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Hannele Seppälä

STUDENTS' SCIENTIFIC THINKING IN HIGHER EDUCATION

Logical thinking and conceptions of scientific thinking in universities and universities of applied sciences

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Helsinki 2013

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Abstract

The purpose of this doctoral thesis is to investigate the two approaches of scientific thinking, more precisely logical thinking and conceptions of scientific thinking as epistemological beliefs of knowledge and knowing, in different contexts in higher education: in universities and universities of applied sciences (UAS), in three different phases of studies, and in the field of economics and business administration. The purpose is to compare students' scientific thinking abilities within the two higher education sectors and in different phases of studies. The study also includes an analysis of the effects of disciplinary and sector-specific factors on students' scientific thinking. In addition, the purpose is to develop the theory of scientific thinking by exploring the connections between the students' logical thinking skills and epistemological beliefs concerning knowledge and knowing. The balance between theoretical and scientific, and professional and practical orientations both in the two higher education sectors, universities and UASs in the field of economics and business administration, creates a context to this study.

The aim of the first part of the study is to investigate students' logical thinking skills including metacognitive awareness of the reasoning process. The focus of logical thinking is on the formal operational stage of thinking and in the hypothetico-deductive causal reasoning process, which include the following sub-reasoning patterns: a) exclusion and control of variables, b) constructing and using formal models, and c) logical reasoning (Inhelder & Piaget, 1958; Adey & Shayer, 1994). Three measures are used to find out students' causal reasoning skills and metacognitive awareness of the reasoning process: Science Reasoning Tasks called the Pendulum, Chemicals for measuring formal reasoning, and the Comparison task for measuring the metacognitive awareness of the reasoning process.

The aim of the second part of the study is to explore students' epistemological beliefs about knowledge and knowing by analysing the students' conceptions of scientific thinking. The qualitative content analysis was applied

to create categories of description of epistemological beliefs on thinking and knowing. In addition, students' conceptions were categorised from the point of view of subjective and objective approaches to thinking and knowing, and through the four dimensions of epistemological beliefs: a) certainty of knowledge, b) simplicity of knowledge, c) source of knowledge and d) justification for knowing (Hofer & Pintrich, 1997).

The aim of the third part of the study is to explore the connections between the development of logical thinking skills and epistemological beliefs on knowledge and knowing and to create an approach which combines the two traditions of scientific thinking. Students' conceptions of scientific thinking in the student group with formal operational thinking skills are compared to the conceptions of students with lower level thinking skills. The aim of the last part of the study is to explore students' conceptions of the skill requirements in higher education and to analyse the effects of the learning environment, aims and epistemological beliefs in the field of business and administration and the two higher education sectors on students' scientific thinking.

338 business major students from five UASs and four universities participated in the study. The results demonstrate that students' logical and metacognitive thinking skills in the two higher education sectors are different. In addition, students' epistemological beliefs concerning scientific thinking in the two sectors are different. However, students' conceptions of scientific thinking proved to reflect the characteristics of the field of economics and business administration. Further, the results show that the two approaches of scientific thinking, logical thinking and conceptions of scientific thinking are related to each other. Differences in the scientific thinking skills between the sectors are interpreted from the perspectives of the different learning environments and knowledge aspirations of the sectors, and of the theoretical and practical orientations of the students.

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OPISKELIJOIDEN TIETEELLISEN AJATTELUN VALMIUDET

Yliopisto- ja ammattikorkeakouluopiskelijoiden loogisen ajattelun taidot ja käsitys tieteellisestä ajattelusta

Tiivistelmä

Väitöstutkimukseni tarkoituksena on tarkastella korkeakouoluopiskelijoiden tieteellistä ajattelua ja sen kehittymistä eri konteksteissa, kauppatieteellisellä tieteenalalla, kahdessa eri korkeakoulukontekstissa, yliopistoissa ja ammattikorkeakouluissa, sekä opiskelun eri vaiheissa. Tutkimuksessa käytetyn teoreettisen viitekehyksen mukaan tieteellisen ajattelun valmiudet sisältävät opiskelijan loogisen ajattelun taidot sekä tieteellisen tiedon luonteeseen ja tietämisen tapaan liittyvät episteemiset käsitykset. Tutkimuksen tarkoituksena on pyrkiä kehittämään tieteellisen ajattelun teoriaa tarkastelemalla loogista ajattelua ja tietoon ja tietämiseen liittyviä uskomuksia toisiinsa. Tutkimus sijoittuu kontekstiin, joka muodostuu kauppatieteellisen alan ja kahden korkeakoulusektorin sisällä eri tavoin vaikuttavista teoreettisista ja tieteellisistä sekä ammatillisesti ja käytännöllisesti painottuneista tavoitteista.

Tutkimuksen ensimmäisen osan tavoitteena on tutkia opiskelijoiden loogisen ajattelun taitojen ja ajatteluprosesseihin liittyvien metakognitiivisten taitojen kehittyneisyyttä. Tutkimus kohdistuu loogiseen ajatteluun ja formaalien operaatioiden vaiheeseen sisältyvään hypoteettis-deduktiiviseen päättelyprosessiin, joka sisältää kolme osaprosessia: a) muuttujien kontrolloinnin ja vakioinnin, b) formaalien mallien rakentamisen ja käyttämisen, sekä c) loogisen päättelyprosessin (Inhelder & Piaget, 1958; Adey & Shayer, 1994). Opiskelijoiden kausaaliajattelun taitoja ja metakognitiivista tietoisuutta on tutkittu kolmella eri menetelmällä: heiluri- ja kemikaalitehtävällä loogisen päättelyn taitoja ja vertailutehtävällä päättelyprosesseihin liittyviä metakognitiivisia taitoja.

Tutkimuksen toisen osan tavoitteena on tutkia tieteelliseen ajatteluun liittyviä käsityksiä. Kyselytutkimuksella kerätyn aineiston analysoinnissa on käytetty menetelmänä sisällönanalyysia. Opiskelijoiden vastaukset on luokiteltu tieteellistä tietoa ja ajattelua koskevia episteemisiä käsityksiä kuvaaviin luokkiin. Lisäksi opiskelijoiden käsityksiä on analysoitu niissä painottuvien subjektiivisten ja objektiivisten lähestymistapojen mukaisesti sekä hyödynnetty teoreettista viitekehystä tietokäsitysten neljästä dimensiosta (tiedon varmuus, tiedon yksin-

kertaisuus ja yksiulotteisuus, tiedon lähde sekä tiedon oikeutus ja perustelu) (Hofer & Pintrich, 1997).

Tutkimuksen kolmannessa osassa tarkastellaan tieteellisen ajattelun kahden eri osa-alueen keskinäistä yhteyttä. Tätä tarkoitusta varten edistyneiden päättelytaitojen omaavien opiskelijoiden tietokäsityksiä verrataan huonommin päättelytehtävissä suoriutuneiden opiskelijoiden tietokäsityksiin. Tutkimuksen viimeisessä osassa tavoitteena on selvittää yliopistojen ja ammattikorkeakoulujen tavoitteisiin, oppimisympäristöihin ja kauppatieteellisen alan tietokäsityksiin liittyviä tekijöitä, joilla on vaikutusta opiskelijoiden tieteellisen ajattelun kehittymiseen. Opiskelijoiden käsityksiä opiskelun edellyttämistä taidoista, ajattelun valmiuksista ja opiskelun tieteellisestä painotuksesta on kerätty opiskelijoilta kyselytutkimuksella.

Tutkimukseen osallistui 338 kauppatieteellisen alan pääaineopiskelijaa viidestä ammattikorkeakoulusta ja neljästä yliopistosta. Tutkimuksen tulokset osoittavat, että yliopisto- ja ammattikorkeakouluopiskelijoiden loogisen ajattelun taidot sekä niihin liittyvät metakognitiiviset taidot ovat erilaiset. Myös opiskelijoiden tieteelliseen ajatteluun liittyvissä käsityksissä on eroja sektoreiden välillä. Tietokäsityksiä koskevat tulokset osoittavat, että opiskelijoiden käsitykset tieteellisestä tiedosta heijastavat kauppatieteellisen tieteenalan tavoitteita ja tietokäsityksiä. Tutkimustulokset osoittavat myös, että opiskelijoiden loogisen ajattelun taitojen kehittyneisyys ja tietokäsitykset ovat yhteydessä toisiinsa. Tutkimustulosten osoittamia eroja yliopisto- ja ammattikorkeakoulusektoreilla tarkastellaan koulutuksen tavoitteiden, oppimisympäristöjen, kauppatieteelliselle alalle ominaisten tietokäsitysten ja opiskelijoiden erilaisten orientaatioiden näkökulmista.

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Kauniainen, December 2, 2012

Hannele Seppälä

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1 INTRODUCTION

The aims of teaching and learning in higher education have changed over the last few decades. The traditional mission of higher education has been to provide education based on scientific research. Besides, the world we are living in today sets several other aims for higher education. During the studies in higher education, students are expected to develop a wide variety of higher-order skills and competencies to be able to work and to be an active member in the knowledge-intensive society where the role of research and knowledge production as the core elements of societal and economic well-being have increased. Expected learning outcomes in today's higher education include research-based expertice and such abilities as understanding the processes of knowledge construction, evaluating the source and validity of knowledge, and applying reasoning skills to produce new knowledge. In addition, different self-management thinking skills are stressed in higher education curricula. Focusing on these academic and scientific thinking abilities is a way to respond to both the traditional and the new challenges of higher education. However, learning such generic skills as scientific thinking has its own aims and processes in universities and universities of applied sciences and is affected by the contextual factors of the learning environment. This doctoral thesis has been inspired by the discussion around higher education students' learning outcomes and the significance of scientific thinking abilities.

1.1 Background and inspiration of the study

The higher education system in Finland consists of two education sectors, universities and universities of applied sciences (UAS).[1] This dual model of higher education was a result of the higher education reform in the 1990s, when UASs were established alongside of universities to offer higher education. The special profiles of the Finnish higher education system and the aims of the research and education in the two higher education sectors create the framework for the present study.

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[1] In the higher education act the translation used is polytechnic. However, all Finnish polytechnics use the term universities of applied sciences in the English names of the institutions. In addition, this translation is also widespread in the contexts of international co-operation between higher education institutions. For these reasons, the term universities of applied sciences (UAS) is used in my study.

1.1.1 Aims and values of research and education in the two higher education sectors

Both higher education sectors have specially defined aims, traditions of research, and educational missions. The mission of the universities is to conduct scientific research and provide undergraduate and postgraduate education based upon it. According to the University Act (558/2009), universities should promote free research and scientific and artistic education, provide higher education based on research, and educate students to serve their country and humanity. In carrying out this mission, universities must interact with the surrounding society and strengthen the impact of research findings and artistic activities on society. According to the UAS act (Polytechnic Act 564/2009), the higher education provided by UASs also has to be based on research. Further, the aim of the UASs is to conduct research and development activities (R&D) which supports instruction and promotes regional development in particular.

Especially at the time when the UAS sector was founded, it was important that the missions and aims were different in both higher education sectors. In that way it was possible to create a new education sector with its own special features to avoid overidentification with the university sector. Since their establishment, the role of the UASs has been to apply the knowledge produced by the universities and to produce knowledge which aims to develop professional fields, working practices and employees (Volanen, 1992). However, this kind of model of traditional roles and the confrontation between knowledge production and application in practice has been criticised and questioned (see, e.g., Gibbons, Limoges, Nowothy, Scharwtzman, Scott & Trow, 1994; Wenger, 1998). Today, in all knowledge production the multidisciplinarity, heterogeneity and applied perspectives are emphasised more than previously (Gibbons et al., 1994). Lampinen (2002) has also criticised the traditional categorisation of research into basic research, applied research, and research and development work, arguing that it does not take into account current development trends in research. Thus, he suggests a new division of research into two types of research: inquisitiveness-oriented research *(in Finnish uteliaisuussuuntautunut)* and application-oriented research *(in Finnish sovellutussuuntautunut)*. The aim of the first is to clarify a phenomenon in order to reach a higher level of understanding. This has traditionally been the aim of the university sector's research. The latter, typically for UASs, is focused more on the product, which could be used in everyday life. The user of the research results in the first case would be a broad group of researchers and experts, while in the latter case the main user would be a customer (Lampinen, 2002). The special feature of research and development in UASs is that it is geared to the needs of business and industry and is usually linked to the structure and development of the regional economy and labour market. Having said that, the aim in UASs is also to produce new knowledge and develop new research methods. Thus, research and development in UASs and research in universities should both aim at quality (Söderqvist, 2004).

In addition to the different nature of research in the two sectors, their degree structures have special features. At the universities students can study for the lower Bachelor's (three years full-time study) and the higher Master's (2 years full-time study) degrees and postgraduate degrees after the Master’s, namely the licentiate and the doctorate. UASs offer education for the UAS Bachelor’s (3.5 – 4 years of full-time study) and the UAS Master's degrees (1.5 – 2 years of full-time study). Degree studies provide a higher education qualification and practical professional skills. The requirement for Master's studies in UASs is a Bachelors'-level degree and at least three years of work experience.

Different educational traditions and ways of defining professional expertise in UASs have an effect on the educational aims and values of the UAS sector. Education in the UASs has its roots in the three different traditions: the expert-novice tradition, the vocational education tradition and the higher education tradition, of which the two latter have the strongest effects on the aims and values of education (Kotila, 2004). According to these traditions, the growth of professional expertise can be defined as cultural attendance, as knowledge acquiring, or as producing new knowledge. In the vocational education tradition both the knowledge structures of professional expertise and reflective skills are emphasised. The growth of expertise is seen through the construction of knowledge and the educational aims emphasise the general skills of working life and professional knowledge. The higher education tradition emphasises the production of new knowledge and the methods of creating innovation-oriented expertise in the curriculum design. In this way the higher education tradition also provides good opportunities for integrating research and development work and education in the UASs. In the UASs this tradition has the most effective impact in those disciplines where the legitimation is received from the university fields operating close to them. Likewise, the higher education tradition only has a slight impact in those disciplines which do not have a counterpart in the university sector. (ibid., 2004.)

1.1.2 Higher education in the field of economics and business administration

The field of economics and business administration is one of the largest in Finnish higher education. In the university sector there are over 16, 000 students and in the UAS sector 23, 000 students (Korkeakoulut 2011 – yliopistot ja ammattikorkeakoulut). Characteristic of research and education in the field of economics and business administration is the dichotomy between academic and scientific, and professional and practical orientations. Research and education are expected to be practically relevant and applicable, but scientific significance and a broad, theoretical orientation are also considered valuable (Kokko, 2003). In Finland, the development of the field has followed both the Humboldtian ideal of science and the European tradition of business education, which has combined the idealisation of pure science and the development of business practices within a scientific framework (Kokko, 2003). In the Finnish context, in addition to the existence of different knowledge orientations inside the field of economics and business administration, the dichotomy of theoretical and practical orientations have an impact on educational aims also on the level of the two higher education sectors, universities and UASs. Figure 1 illustrates the dichotomy of the theoretical and practical orientations in universities and UASs in the field of economics and business administration.

Another characteristic of the field of economics and business administration is its interdisciplinary basis. The field includes a wide variety of disciplines in economics and business economics (e.g., marketing, accounting, finance and business management). Barnes (1995, 32) has summarised the definition of the field as follows: "Business education is a field of study which is based on interdisciplinary enquiry. It is an approach which uses a variety of different academic disciplines. It has a practical application in work and is the study of the physical and human resources of an organization."… "Because of its broad base it draws on the analytical tools of both the physical sciences such as mathematics, and the social sciences to find solutions to those problems it identifies as its area of concern. It is precisely this combination of problems from the business world and the selected analytical tools of the physical and social sciences which provides its unique identity as a taught course at undergraduate or postgraduate level."

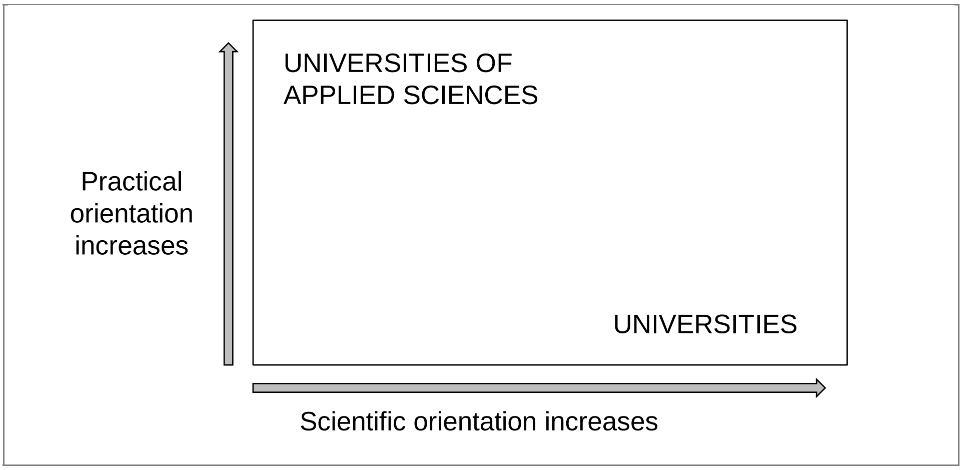

Figure 1. Dichotomy of the theoretical and practical orientations in the field of economics and business administration in universities and UASs (modified, Kokko, 2003).

1.1.3 Generic skills as expected learning outcomes in higher education

One of the most significant changes in higher education during the 21st century has been the growth of the demands of working life. In the changing global economy, high quality tertiary education is seen to be essential in producing economic, scientific and social progress. One of the reactions to the demands of the surrounding society is the Bologna Process, which is a broad European-level development process of higher education. The objective of the Bologna Process (started in 1999) is to develop the European Higher Education Area by establishing a two-cycle degree structure, easily comparable degrees and a harmonised system of credits in European higher education. In the degree reform process, special attention has been paid to higher education students' qualifications and the reform and analysis of the curriculums are conducted from the perspective of learning outcomes. At the European level, the process of constructing the European Qualifications Framework (EQF) has aimed to develop transparent descriptions of the knowledge, skills and competencies to be acquired at each level of higher education degrees. Further, the aim has been to use the EQF as a reference tool to compare the qualification levels of the different qualifications systems and to promote both lifelong learning and equal opportunities in the knowledge-based society. As a continuum to the EQF project, the European Commission has also released a framework for key competences for lifelong learning, which identifies and defines the key abilities and knowledge needed in achieving employment, personal fulfilment, social inclusion and active citizenship in today's world. The framework includes such general skills as learning to learn, social and civic competence, initiative-taking, entrepreneurship, cultural awareness and self-expression. (European Parliament Council, 2008; Ministry of Education, 2005, 2009.) [2]

One example of the emphasis on the learning outcome-oriented approach and the pressure to conduct performance assessment is the Organisation for Economic Co-operation and Development (OECD)'s initiative to establish Assessment of Higher Education Learning Outcomes (AHELO)[3]. The focus of the assessment is on final-year bachelor degree learners' capacity to use, apply and act on their knowledge and reasoning. Thus, the aim of the assessment is to provide actual data on the quality of learning and its relevance to the labour market. AHELO assessment will look both at the skills that students in all fields should be acquiring and skills that are specific to each discipline. Also the students' learning environment and other contextual aspects and the effects on students learning are analysed. (Hamish & Richardson, 2011.)[4]

Through these development processes, the discussion of definitions of the key competencies and generic skills has become crucial in higher education. Still, the research area of students' generic skills in higher education is fragmented and includes different levels of approaches. However, the term is used in various ways by different actors (employers, academics and government bodies) and has numerous synonyms, such as generic attributes-, graduate attribute- and generic capacity (e.g., Badcock, Pattison & Harris, 2010; Ursin & Hyytinen, 2010). This causes challenges in linking the research and comparing the results within the research area. Typical to the definition of generic skill is that it is a skill or a competence which can be applied in working life and modern society in general (Rychen & Salganik, 2003). Further, generic skill is often defined as a skill or attribute that is beyond disciplinary content knowledge and can be broadly applied across different contexts (Badcock et al., 2010). The perspective of scientific thinking as a higher education learning outcome is clearly visible in the lists of generic skills, which suggest for example such skills as analytical and critical thinking, problem solving, research skills, reflective thinking, a capacity for logical and independent thought, communication and information management skills, interpersonal skills, intellectual curiosity and rigour as well as creativity (e.g., Badcock et al., 2010; Barrie, 2006; Bennett, Dunne & Carré, 1999; Pitman & Broomhall, 2009; Tynjälä, Slotte, Nieminen, Lonka & Olkinuora, 2006).

As in the academic research literature, scientific thinking skills are also emphasised in the European level higher education policy documents and international learning assessments. In the context of EQF, the skill descriptions (defined to different levels of degrees) involve the use of logical, intuitive and

[2] For more information see www.ec.europa.eu/education

[3] The AHELO feasibility study commenced in 2010 and is scheduled for completion in 2012. In 2013, the OECD will be determine if the AHELO assessment will be further developed.

[4] For more information see www.oecd.org

creative thinking (cognitive aspect). The other aspect in descriptions is practical involvement e.g., the use of methods, materials, tools and instruments. Both the Bachelor's - and Master's -level descriptions (levels 6 and 7 in EQF) include skills, which prepare students with scientific thinking. The skill description of the Bachelor's -level degree indicates that students should have "advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study" (European Parliament Council, 2008, 5). At the Master's level (level 7 in EQF) students should have "specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields" (European Parliament Council, 2008, 5). In the knowledge descriptions the aspects of students' epistemological development are included: knowledge at the level of the Bachelor's degree (level 6) is advanced knowledge of a field of work or study and students are supposed to have a critical understanding of theories, methods and principles. At the Master's level the knowledge is more specialised, and the knowledge is applied as the basis for original thinking and/or research. Students at the Master's level have critical awareness of knowledge issues in a field and at the interface between different fields. The indications of the significance of scientific thinking skills in higher education students are also clearly visible in the AHELO assessment, which include such skills as analytical reasoning, critical evaluation of knowledge and identification and acceptance of contradictions in knowledge. Further, the assessment focuses on the skills of logical thinking, identification of consistent logical deduction and the skills of drawing conclusions on the base of logical deduction. The emphasis of scientific thinking skills in the international guidelines and assessments of learning outcomes activates the discussion around the skills of scientific thinking and enhances the development of the skills in higher students' learning.

1.2 Purpose and research questions

The purpose of this doctoral thesis is to investigate students' scientific thinking skills, more precisely logical thinking and conceptions of scientific thinking in different contexts in higher education, namely in universities and UASs, in three different phases of studies, and in the field of economics and business administration. In addition, the purpose is to develop the theory of scientific thinking by exploring the connections between students' logical thinking skills and epistemological beliefs on knowledge and knowing (see Figure 2.).

Scientific thinking can be defined in various ways. It connects to different forms of thinking studied by cognitive psychologist, such as inference, problem-solving, critical thinking and argumentative thinking. In Kuhn's (2010) theoretical meta-analysis scientific thinking is defined e.g. as reasoning strategies, as purposeful knowledge seeking, as intentional coordination of theory and evidence, as conceptual change, and as strategies of theoretical understanding which encompass the cycle of scientific investigation, namely the phases of enquiry, analysis, inference, and argument.

The construction of my research design by selecting the logical thinking and epistemological beliefs as the main focus in investigating students' scientific thinking is inspired by three aspects. The first motive is the importance of these skills in the age of knowledge society as the skill requirements in working life and the role of scientific knowledge have changed. Logical thinking skills and epistemological beliefs are needed in understanding and evaluating knowledge in the different situations of problem solving and decision-making, in acquiring scientific literacy, and in the use of scientific methods to produce new knowledge. Thus, these skills have also been referred to as generic skills in the recent research and discussion on higher education students' qualifications (e.g. in the processes of EQF and AHELO, see Chapter 1.1). The second reason for the research design arises from the specific nature of the research area of adult cognitive development. The traditions of developmental psychological models (including logical thinking) and epistemological beliefs provide a comprehensive framework for studying students' scientific thinking skills, because beside the general research tradition of adult cognition these two traditions represent the main lines of research in the area of adult thinking (see Kallio 2011). The complexity of the research area has also been taken into account in the construction of the research design also. Several meta-theoretical analyses (e.g., Marchand 2001, Hoare 2006, Kramer 1983, Kallio, 2011) have revealed that the use of the concepts and labels describing the higher stages of adult development is not systematic. For these reasons the specification of the research areas under clearly defined topics (e.g. causal thinking, epistemological thinking, critical thinking etc.) has been recommended (e.g., Kallio & Liitos, 2009). Following this, the framework consists of the two separately defined research traditions of scientific thinking. In that way the research design in my study also provides an alternative framework for e.g. post-formal models in the conceptualisation of adult higher order thinking (see Chapter 2.1). The third motive for the research design is that both logical thinking and epistemological beliefs in students have been investigated widely in previous research (see Chapters 2.1 and 2.2), but the research analysing the connections between these abilities is rare (see Chapter 2.3).

Further, the research design compares students' scientific thinking abilities between the two higher education sectors and in different phases of studies in the field of economics and business administration. The balance between theoretical and scientific, and professional and practical orientations at the two higher education sectors as well as inside the field of economics and business administration create a context to my study. The main interest behind the selection of the two higher education sectors in the research design is the aim to provide information on students' scientific thinking skills for the development of teaching and learning in both sectors. Traditionally scientific knowledge and research have had a fundamental role as a basis for teaching and learning not only in universities, but during the latest decade also in UASs. In the future, the role of research, development and innovation activities will be further strengthened in both higher education sectors.[5] In addition, the research includes the analysis of disciplinary and sector-specific factors affecting students' scientific thinking and conceptions concerning the role and emphasis of scientific thinking in studies. The results of the previous research have shown that the ways of scientific thinking of students are affected by the social and academic context, for example by the disciplinary and sector-specific factors including the aims, epistemological beliefs, the characteristics of the learning environment and the cognitive goals set for students' learning (e.g., Biglan, 1973a, 1973b; Becher, 1994; Neumann, 2001; Neumann, Parry & Becher 2002; Lueddeke, 2003; Lindblom-Ylänne, Trigwell, Newgi & Ashwin, 2006). In order to assess and develop students' scientific thinking skills, the effects of the learning environment in the two sectors and in the field of economics and business administration are explored.

The theoretical framework of this study is based on the two research traditions of scientific thinking. First, the theoretical foundation of investigating students' logical thinking skills is based on previous research focusing on the development of causal reasoning and hypothetico-deductive reasoning processes involved in logical thinking (e.g. Piaget, 1972; Adey & Shayer, 1994; Lawson, 2004; Lawson et al., 2007 and in Finland e.g., Kallio, 1998) and metacognitive abilities that are linked to the reasoning process (Demetriou & Efklides, 1985; Demetriou, 1990; Demetriou & Efklides, 1990, Demetriou, Spanoudis & Mouyi, 2011). In the present study the term logical thinking is used to refer to these reasoning processes. The theoretical foundation of this part of the study is mainly based on the Piagetian tradition concerning cognitive development. Second, the study of students' conceptions of scientific thinking builds on previous research on the development of epistemological beliefs on knowledge and knowing (personal epistemology) (e.g., Perry, 1968; King & Kitchener, 2002; Baxter Magolda, 1992; Hofer & Pintrich, 1997; Kuhn, Cheney & Weinstock, 2000; Kuhn & Weistock, 2002; Hofer, 2002, and in Finland e.g., Lindblom-Ylänne, 1999; Lonka & Lindblom-Ylänne, 1996; Lonka, 1997; Pirttilä-Backman & Kajanne, 2001; Kaartinen-Koutaniemi, 2009) and especially on the four dimensions of epistemic beliefs: a) certainty of knowledge, b)

[5] The amendment of the University Act came into force in 2009 and the amendment of the Polytechnic Act will be ratified in 2014.

simplicity of knowledge, c) source of knowledge and d) justification for knowing (Hofer & Pintrich, 1997; Hofer, 2002, 2004a).

My research questions are the following:

1. What are the logical thinking skills and abilities of its metacognitive awareness among the higher education students in the field of economics and business administration?
    1.1 Are there differences in these reasoning processes between the higher education sectors?
    1.2 Are there differences in these reasoning processes between the study phases (initial, intermediate and final)?
    1.3 What are the effects of the individual factors on these reasoning processes (gender, age, prior education)?

2. What are the students' conceptions of scientific thinking?
    2.1 Are there differences in these conceptions between the higher education sectors?
    2.2 Are there differences in these conceptions between the study phases (initial, intermediate and final)?

3. What are the connections between the two studied traditions of scientific thinking?

4. What are the students' conceptions of skill requirements in higher education studies as well as the conceptions of the role of scientific thinking in studies?

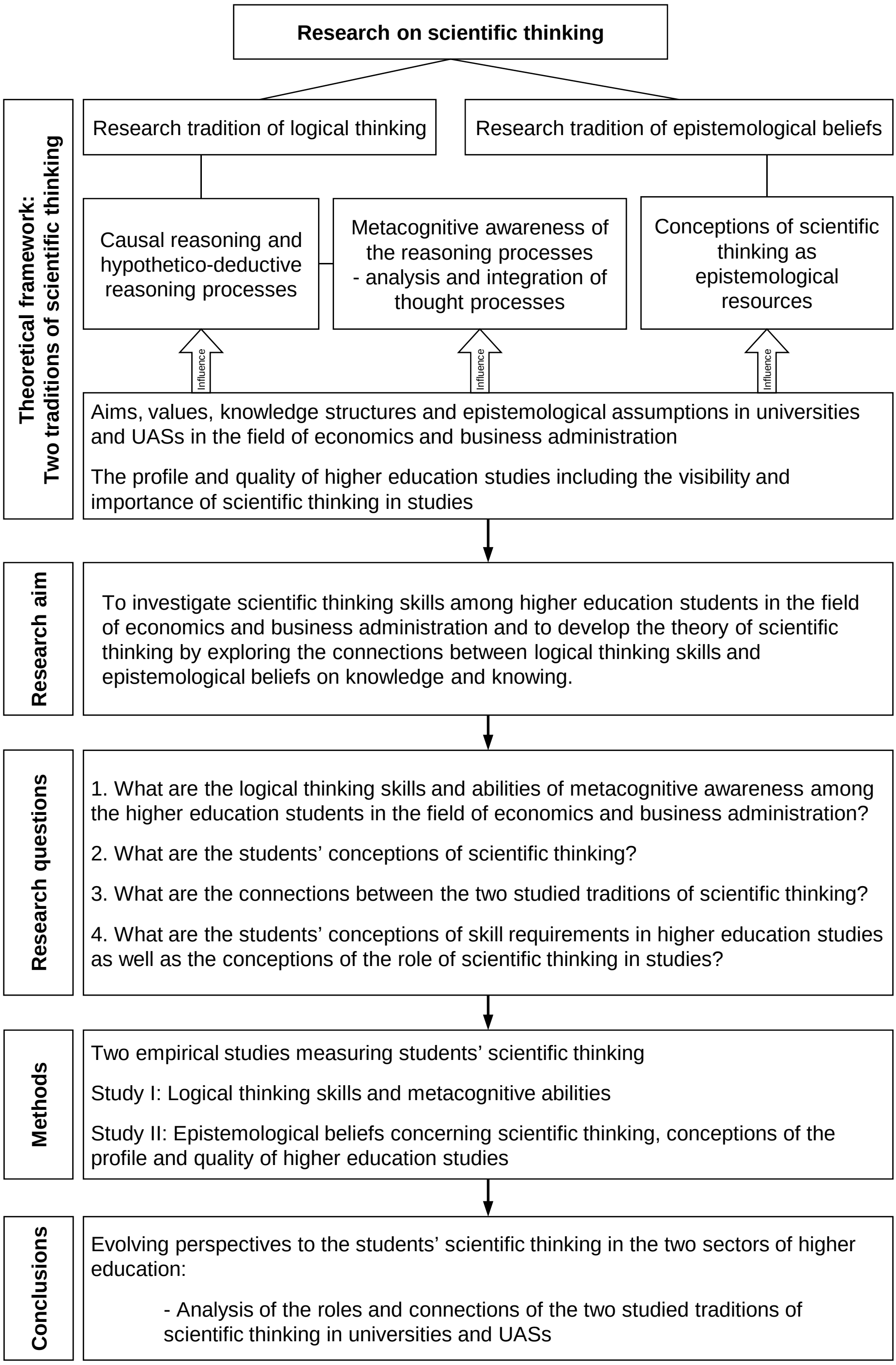

Figure 2. The research frame.

2 PREVIOUS RESEARCH

The theoretical foundation of my study is based on the two research traditions of scientific thinking: logical thinking and epistemological beliefs on knowledge and knowing. Further, the theoretical foundation integrates the two traditions of scientific thinking and provides a framework for investigating the relations between them. The construction of the theoretical foundation of my study is in line with the main lines of research on scientific thinking under the rubric of adult thinking. Research under the tradition of logical thinking has been conducted both in Europe and the United States, whereas the research under students' epistemological beliefs has mainly been focused in the United States (Hofer & Pintrich, 1997). However, during the last few decades research on epistemological development has increasingly spread to Europe and to Asia (Hofer, 2008). In Finland, students' scientific thinking has been explored starting from the 80s under both research traditions. Kaartinen-Koutaniemi (2009) has summarised the lines of research on students' scientific thinking in Finland and according to her analysis the main focus of research during the 80s and 90s has been on the development of epistemological beliefs (e.g., Lindblom-Ylänne, 1999; Lonka, 1997; Aittola, 1992; Järvinen, 1985; Stenfors, 1999; Kaartinen-Koutaniemi, 2009). The other lines of research have been the application of King's & Kitchener's reflective judgment model in exploring epistemological thinking in adulthood (e.g., Pirttilä-Backman & Kajanne, 2001) and the research of students' logical thinking skills based on the Piagetian theory of cognitive development (e.g., Hautamäki, 1983; Hautamäki, Arinen, Bergholm, Hautamäki, Kupiainen, Kuusela, Lehto, Niemivirta & Scheinin, 1999; Kallio, 1998; Kuusela, 2000).

The research on the contextual and discipline-specific effects on knowing and reasoning is a research area which is closely linked to the skills of students' scientific thinking. Differences in academic culture, learning environment, knowledge structures and epistemological assumptions of disciplines are analysed in several studies (Biglan, 1973a; Becher, 1994, Becher & Trowler, 2001; Donald 1990, Hofer, 2000; Neumann, 2001; Neumann et al., 2002; Lueddeke, 2003; Lindblom-Ylänne et al., 2006; Ylijoki, 2000; Palmer & Marra, 2004; Buehl & Alexander, 2001, 2006).

This chapter first gives an overview to research on scientific thinking under the two traditions of scientific thinking. Then, the theoretical framework including the definitions of logical thinking and epistemological beliefs applied in my study are presented. In Chapter 2.3 the two research traditions are tied together and the connections between them are discussed. In Chapter 2.4 some discipline-specific factors are discussed which have been shown to influence different ways of thinking. Chapter 2.5 summarises the previous research and presents the perspectives adopted by my study.

2.1 Logical thinking skills

Logical thinking and reasoning skills have been studied for a long period of time within developmental psychology, educational psychology and especially within science education (see e.g. Lawson, 2004; Lawson et al, 2007). The research tradition of logical thinking can be divided into three categories of research approaches (see Table 1.). The first category consists of the research focused on causal reasoning at the stage of formal operations. In this category the most influential theory and attempt to define the key elements in the reasoning process has been Inhelder's & Piaget's (1958) theory on the development of logical thinking. In that model the cognitive operations at the stage of formal operational thinking are seen as fundamental for scientific thinking. Some scholars, for example Shayer and colleagues (Adey & Shayer, 1994) have followed this original theory without formulating or adding new elements to it. The second category consists of the models that are based on Piaget's theory, and broadened with the skills that fit the skill variation at the formal operational level, but are not as such included in the original Piagetian model. The models of the development of thinking, which include metacognitive awareness concerning the thinking processes, can be positioned under this category (e.g., Demetriou & Efklides, 1985; Demetriou, 1990). The third category of research is focused on the new logical development models that are built after the Piagetian framework and which are based more or less on Piaget's theory premises (e.g. Fischer, 1980; Commons & Richards, 1984a, 1984b; King & Kitchener, 2002; Lawson, 2004, Lawson et al, 2007). Many of these theories are constructed by extending the Piagetian model along the vertical dimension by adding higher cognitive stages, which are called 'post-formal operations'. So far it has remained unclear if the cognitive operations described in the new models (e.g. Commons et al, 1984a; Commons et al, 1984b; Fischer, 2003; Lawson, 2004) represent well-developed operations of formal operational thinking or is it really possible to speak about a new stage of cognitive development (Kallio & Liitos, 2009). However, some researchers have requested more exact conceptual analysis on the characteristics of these post-formal models (Marchand, 2001; Kallio & Liitos, 2009; Kallio, 2011).

Table 1. The research tradition of the development of logical thinking and the central features of approaches within this tradition.

	Research tradition of logical thinking		
	Approaches		
	Causal reasoning at the stage of formal operations	**Models extending the Piagetian model with additional skills at the stage of formal operations**	**Models of post-formal thinking**
Central feature of the approach	Hypothetico-deductive causal reasoning process	A broader variation of thinking skills, including e.g. metacognitive awareness of thinking processes	Acceptance and integration of various truths, contextuality of thinking

In my study the focus is on the first two research approaches of logical thinking: the causal reasoning processes at the stage of formal operations (described in Chapter 2.1.1) and the metacognitive awareness on reasoning, which is an approach that represents models which extend the original Piagetian theory (the Chapter 2.1.2). In chapter 2.1.3 the view to logical thinking is widened by describing the research area of logically more complex cognitive operations (so-called post-formal thinking). The aim is to give an overview of the development of research focused on logical thinking skills from the 1970s until the present time.

2.1.1 Causal reasoning at the level of formal operations

According to the perspective adopted by my study, causal reasoning is the key reasoning process in logical thinking. The problem-solving situations that include causal reasoning activate various thinking processes and the use of several reasoning patterns. These processes include identification of a problem and the generation and testing of alternative explanations to the problem. Later in the reasoning process during in the data analysis phase, after testing and collecting the data, other thinking abilities are needed to evaluate, compare and combine different claims and solutions (e.g. such reasoning patterns as probabilistic, proportional and correlational reasoning) (Lawson, 2004). The very beginning of the reasoning process which involves identifying an appropriate question as the object of investigation and the ability to generate one or more hypothesis is a challenging one and contributes significantly to success (Kuhn et al, 2008). This process is called the hypothetico-deductive reasoning process. The key sub-pattern in hypothetico-deductive reasoning that guides the construction of 'controlled experiments' is the attempt to identify and control independent variables (Inhelder & Piaget, 1958, see also Adey and Shayer, 1994).

From the point of view of logical thinking, the most important sub-reasoning processes of causal reasoning are the following: 1) exclusion and control of variables, 2) constructing and using formal models and 3) logical reasoning (Kallio, 1998). The focus is especially in the construction of experiments, which means that one chooses pairs of experiments for further analysis, which is an important innovation of advanced 'variable-centred reasoning'. This reasoning pattern requires the ability to hold several independent variables and one dependent variable in mind, and consider the possible effects of each independent variable on the dependent variable. The exclusion of irrelevant variables requires the identification of variables that do not have any effect. The schema 'exclusion and control of variables' plays an important role in causal reasoning (Inhelder & Piaget, 1958), but also implicitly or explicitly in all experiments or critical investigations (Adey & Shayer, 1994). The variable-controlling strategy is valid not only in the natural sciences, but also in social studies, where the strategy is more subtle since the variables are not always obvious as they interact with one another and are often impossible to control (Adey & Shayer, 1994). Its importance is in its ability to isolate the factors which may possibly have an effect on an event, to consider each of them in turn and all together, and to make rational assessment of their relative contributions to the effect (Adey & Shayer, 1994). The understanding of the combinatorial system of variables is the prerequisite for the schema which controls the variables. Besides the ability to include the causally relevant variables, the exclusion of irrelevant variables also plays a crucial role. In other words, it is important to be able to make a logical deduction of the role of every variable based on the experiments and to demonstrate if some factor is a causal agent, and which other variables have no effect (Inhelder & Piaget, 1958). Haaparanta and Niiniluoto (1990) have also noted that, from the philosophical perspective, logical hypothetico-deductive reasoning is domain-general in the sense that it can be applied across all the disciplines.

The ability to construct and use formal models is the second important element in scientific reasoning. The working model has different parts which move and hold the same relationships to one another. 'Moving parts' in a formal model are abstract entities which have to be imagined. Formal models can be constructed in the natural sciences, for example in chemistry, but also in the social sciences. The construction of formal models requires the mental manipulation of many variables together (Adey & Shayer 1994). Logical reasoning is the ability to analyse the combinatorial relations present in the information given. The logical operations - implication and the denial of implication - are examples of logical reasoning (Adey & Shayer 1994).

The development of causal reasoning skills

According to Piaget's and Inhelder's cognitive development theory (Inhelder & Piaget, 1958) hypothetico-deductive reasoning is possible when the formal operational development stage is reached. In the Piagetian theory of the development of logical thinking, this development includes four stages from childhood to adolescence and adulthood. The four developmental stages (sensorimotor, preoperational, concrete operational and formal operational) are called equilibrated states of intellectual development, which means that after each developmental stage clear qualitative changes in thinking occur. According to Piaget (1976a), contradictory and different experiences in contrast to already-formed ways of action (schemata) are the preconditions for developmental change. Reflective abstraction occurs when an individual is prompted by contradictory feedback (in the physical environment or in social interaction with other people) and the result is that the individual gains declarative knowledge and also becomes more aware and conscious of this knowledge. The skills required to acquire knowledge also improve in this process (Lawson, 2004). The development of thinking and the differences between individuals depend on the social environment, acquired experience and intellectual stimulation besides the aptitudes, personal interest areas and professional specializations of the individuals (Piaget, 1972). Depending on these factors, there are great differences between individuals in the skills of formal thought: some individuals will reach the level of formal thought later than others or it may never really take shape.

The formal operational stage of cognitive development includes a qualitative and equilibrative restructuring of thinking. According to Piaget (1972, p.6) "[formal thought] is a complex but coherent system that is relatively different from the logic of the child, and constitutes the essence of the logic of cultured [educated] adults and even provides the basis for elementary forms of scientific thought". The period of formal operational thought provides the individual with the capacity to handle hypothetical and theoretical possibilities and reason in terms of verbally stated hypotheses. To reason hypothetically and to deduce the consequences that the hypotheses necessarily imply is a formal reasoning process.

2.1.2 Development of metacognition focused on reasoning process

The concepts of metacognition and reflection are popular within higher education as they are regarded as essential elements in the development of expertise and higher order thinking. Thus, the field of research on reflection in higher and adult education is broad, but also incoherent with different theoretical and philosophical bases as well as conceptual connections within the theories and varying cognitive and emotional aspects in the theories (for a metatheoretical analysis, see Mälkki, 2011). However, in my study the focus of metacognition is limited to the cognitive operations of reasoning processes. In other words, my interest is in the process of thinking about thinking, which implies the potential for active self-directed management of thinking and direction of cognitive resources in a consciously controlled way. The assumption behind this is that higher self-awareness and the ability to judge the status of problem-solving enables individuals to perform better in educational settings and to become effective in handling the learning and problem-solving process (Demetriou & Bakracevic, 2009). As a result of this, differences between individuals are already forming in childhood, but especially during adolescence and adulthood (Kuhn, 2008).

Metacognition as a concept has varying definitions in the literature. In history, Flavell (1976) was the first researcher who used the word ‘metacognition’. He described it in the following words: “Metacognition refers to one’s knowledge concerning one’s own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact.” (Flavell 1976, p. 232). Consistent views across the different definitions for metacognition can be summed up as: the awareness of one's thinking, active monitoring of cognitive processes and regulation of cognitive processes (Hennessey, 2003). Metacognitive processes may include an intentional component or more automatic components, which both have a place in cognitive operations. Intentional level involves “students’ ability to engage in purposeful and evaluative thought over disconnected elements of knowledge to purposefully assemble or connect pieces of knowledge” (Hennessey, 2003, 126). Also Piaget’s cognitive development theory includes several conceptions of reflective thinking. In his theory the concept ‘reflected abstraction’ is used to refer to the metacognition that is connected to logical reasoning (Inhelder & Piaget 1958; 1972). According to Piaget (1972), reflected abstraction is possible when hypothesis testing, evaluation and imaginative abilities of possible words have been developed. Reflective abstraction is a propelling force and mechanism for the individual’s cognitive development (Piaget, 1972).

Demetriou and his colleagues have developed during the last few decades models of cognitive development, which include the element of metacognitive development connected to formal operational reasoning (Demetriou & Efklides, 1985; Demetriou, 1990; Demetriou & Efklides, 1990; Demetriou & Kazi, 2006; Demetriou & Bakracevic, 2009; Demetriou et al., 2011). According to their models, awareness of cognitive processes and cognitive control are tightly related with the development of deductive reasoning. These metacognitive skills enable the thinker to search systematically for and envisage the relations suggested by the premises of an argument and their relations (Demetriou et al., 2011). Demetriou and his colleagues (Demetriou et al., 2011) have described the reasoning process at the metacognitive level as follows: reasoning emerges through awareness of similarities and differences between heuristic processes and the construction of representations that unify and represent these heuristic processes. This means that in the reasoning process the key components of reasoning are metarepresented as logically necessary reasoning schemes, which are interconnected with each other as reasoning rules. The development of the metacognitive awareness can be described using the following levels: (i) the level of no conscious reflection, (ii) the level of content-based reflection, (iii) specification of the cognitive operations involved, and (iv) analysis and integration of cognitive operations (Demetriou & Efklides, 1985; Demetriou, 1990). According to Demetriou's model, metarepresentation is a process that enhances understanding and problem-solving efficiency. As in Piaget's reflective abstraction, metapresentation abstracts general patterns from different mental functions or activities and reorganises them at a higher, more efficient representational level (Demetriou et al, 2011).

2.1.3 Development of logical thinking skills in the light of the later models

One of the categories of research approaches on logical thinking is focused on the operations, which are supposed to be logically more complex than formal operations (so called 'post-formal operations'). The category consists of the new logical development models that are built after the Piagetian framework between the 70s and the present decade.

Despite the fact that Piaget's developmental theory has had a significant impact on cognitive developmental psychology, it has also been criticised widely since the 70s on the grounds that it is conceptually and empirically limited, or philosophically and epistemologically untenable (Laurenco & Machado, 1996). Nevertheless, many of the later-built models are still based more or less on Piaget's theory premises and are constructed by extending the Piagetian model along the vertical dimension by adding higher cognitive stages (e.g. Fischer, 1980; Fischer, Yan & Stewart, 2003; Commons & Richards, 1984a, 1984b; King & Kitchener, 2002; Lawson, 2004, Lawson et al, 2007).

In this chapter some aspects of the criticism towards Piaget's theory of formal operations are discussed and the main models suggesting new definitions of higher order thinking are presented.

Criticism towards Piaget's theory of formal operations as representing higher-order adult thinking

Piaget's theory of the development of thinking and the role of the theory as representing higher-order adult thinking has faced considerable criticism (see, e.g., Marchand, 2012). From the point of view of scientific and logical thinking the most adequate criticism includes the nature of logic the Piagetian theory represents and the possibilities of the theory taking into account intermediate variables of the social components and context (Alexander, Druker & Langer, 1990). Piaget's view has been interpreted to represent so-called hard logic (the logic of truth, binary logic) and it has been distinguished from more flexible logic which, although containing the former, would be less restrictive and would better explain the complexity of adult thought (Labouvie-Vief 1984; Marchand 2001). According to Labouvie-Vief (ibid.), hard logic is manifested in the exhaustive search for truth, while flexible logic takes into consideration different and, at times, conflicting points of view (logical relativism). The theories which have the objective of providing a more expanded view of adult thought have presented the view that the distinctive characteristic of adult thought is the acceptance and integration of various, and at times incompatible, truths which are highly dependent upon context (Kramer, 1983; Marchand, 2001). For these theorists of dialectical thought (e.g., Kramer, 1983), development consists of continuous and constant changes in which contradictions are the motor of advances without providing stable levels of equilibrium. Thus, the central feature of adult thinking in models of post-formal thinking is the relativistic thought and ability to understand complex relationships with fuzzy logic and ill-defined problems, with no clear-cut objective solution (Baltes & Staudinger, 2000; Kramer, 1983; Kitchener, King & DeLuca, 2006; Kallio 2008). Strengthening of the role of autonomy and the idea of subjectivity becomes a part of knowledge formation in adulthood. Adults are more suspicious than younger people about the possibility of pure objective knowledge and are aware of the fact that e.g. personal preferences, values, attitudes, worldviews and life experiences influence the thinking processes (Labouvie-Vief & Diehl, 2000; Kallio 2008).

In addition, later researchers have also criticised the structure of the stage of formal operations. In Piaget's theory there are different substages of thought in the formal stage (e.g. early formal thinking to full operational formal thinking), but the components of formal operational thought are claimed to emerge together as a tightly structured whole. For example, Kallio (1998) and Kuhn (2008) have noted that the empirical evidence does not support the claim that the structure is coherent from the point of view of the subject. The development from one stage to the next is never linear or an absolute, strictly limited construct. According to researchers (Kallio, 1998; Kuhn, 2008), there are always minor sub-stages inside major stages as well as transitional sub-stages between stages. The development may contain both progressive and regressive components at the same time. In addition to the structure of the formal operational stage, criticism has been focused on the definitions of the concept of stage (e.g., Marchand, 2001). However, the strengths and weaknesses of stage models have been widely discussed in cognitive development literature and criticisms are common not only in the area of logical thinking models but also concerning models of epistemological thinking. According to Kuhn and Weinstock (2002, 123), “A significant weakness of stage models that depend on multiple, diverse characteristics to define each stage, however, is a lack of cohesion with respect to these characteristics, such that it is not clear what defines the ‘essence’ of the stage, and particularly, what drives the movement from the diversity of characteristics defining one stage to those defining the next.”

However, some researchers have tried to avoid this kind of confrontation between Piaget’s theory and later theories (e.g., Laurenco and Machado, 1996, Machand, 2012). They have reminded us that the criticism towards Piaget’s theory too often forget the dialectical, constructivist and developmental nature of Piaget’s approach to human development. Also the role of reflective abstraction, which integrates formal operational thinking with other psychological and cognitive development areas, is often forgotten. Further, the formal operations can be seen to be general to adult thinking in all domains, not only in experimental and logico-mathematical thinking. However, as was stated earlier, it is typical that an individual can reason at this level only in some domains (Piaget, 1972) and reasoning varies from time to time (Kuhn, 2008). In other words, the formal operational structure can be defined as a domain-general structure, but from the point of view of the single individual the structure may be considered as domain-specific ability. Different individual profiles and interests should be taken into account as contextual variables in the development of thinking. According to Piaget (1972), differences between individuals depend on the social environment, acquired experience and intellectual stimulation besides the aptitudes, personal interest areas and professional specialisations of the individuals.

Models of post-formal thinking

The research of the post-formal models, which focuses on logical thinking is rather limited. Remarkable theorists within this research tradition have been Fischer (1980, Fischer et al., 2003), Lawson and colleagues (Lawson, Banks & Logvin, 2007) and Commons and colleagues (Commons & Richards, 1984a, 1984b; Commons & Bresette 2006). The models of these theorists are presented in this chapter as examples of the constructions of post-formal models.

Fischer (1980) was among the first scholars who re-examined Piaget’s theory of cognitive development by introducing the skill theory, with 10 hierarchical developmental levels. Later Fischer and colleagues (Fischer et al., 2003) have extended the traditional ladder-like model of cognitive development by introducing a model of developmental webs. According to the idea of developmental webs, adult cognitive development is a complex process of dynamic construction within multiple ranges moving in multiple directions (Fischer et al., 2003).

According to the model of intellectual development introduced by Lawson and colleagues (Lawson et al., 2007), development proceeds from a descriptive stage (similar to Piaget's concrete operational level) to two more advanced stages (formal and so called post-formal stages). The first one of these advanced stages corresponds with Piaget's formal operational stage, where causal hypotheses are generated and tested, but only when the hypothesised causal agents are perceptible. The second advanced stage is called post-formal and at this stage it is possible for individuals to generate and test hypotheses involving nonperceptible theoretical entities. Lawson (ibib.) argues that the distinction between perceptible and nonperceptible causal agents in reasoning makes post-formal reasoning presumably more abstract and complex than formal reasoning. Lawson et al (2007) have assessed the reasoning abilities of university students by a test that measures the elements of reasoning and hypothesis testing (i.e. identification and control of variables, correlational reasoning, probabilistic reasoning, proportional reasoning and combinatorial reasoning).

Commons and colleagues (Commons & Richards, 1984a, 1984b, Commons & Bresette 2006) have constructed a model of hierarchical complexity (MHC), which has been recognised as a remarkable attempt in the logical thinking domain to describe the higher stages of adult development (see, Kallio 2008). The model is derived in part from Piaget's notion that higher-stage actions coordinate lower-stage actions by organising them into a new, more hierarchically complex pattern (Commons & Bresette, 2006). However, Commons and coworkers (Richards & Commons, 1984) describe higher development stages in the MHC model as being qualitatively distinct from and logically more complex than that of formal operations. [6] In these stages subjects become progressively capable of analysing and coordinating diverse systems and creating supersystems of a metatheoretical nature. MHC is also an attempt to develop a general way to specify the organisation of tasks in any domain (as opposed to being content bound). The developers of the model have also illustrated the relationship between domain-general higher order thinking and creativity.

Kuhn and colleagues (Kuhn, Iordanou, Pease & Wirkala, 2008) have introduced the model of multivariable scientific reasoning. They have identified three aspects of scientific thinking beyond the control of variables strategy (which is the key element in hypothetico-deductive reasoning): 1) the ability to coordinate the effects of multiple causal influences on an outcome, 2) a mature understanding of the epistemological foundations of science, and 3) skilled

[6] Commons has in his latest writings (e.g., in the forums of ESRAD, SRAD) used only the term 'hierarchical complexity of thinking', not the term 'post-formal thinking'.

argumentation coordinating theory and evidence. Kuhn and her co-workers' view underlines the important roles of all three, but they do not claim anything about the relations among these competencies nor their relative importance in scientific thinking. In Kuhn and her colleagues' (ibid.) theoretical framework the control of variable strategy is not as important as the ability to take all the relevant effects into account with the objective of predicting how they will jointly affect an outcome. However, this multivariable scientific reasoning has so far had relatively little attention in the research of scientific thinking.

In order to avoid conceptual and theoretical incoherence, Kallio (2008) has suggested the use of the term 'integrative thinking' in place of terms 'post-formal thinking' or 'relativistic-dialectical thinking' for advanced adult cognition. Integration is a concept that appears in many research domains (logical, conceptual, intra-psychological and inter-social) and it is used in describing the cognitive ability, for example, to transform different elements or create upper-level synthesis (Kallio, 2008).

2.2 Epistemological beliefs of knowledge and knowing

The research tradition on epistemological beliefs aims to understand how individuals develop conceptions of knowledge and knowing and to utilise them in understanding the world (Hofer, 2006). In scientific thinking the beliefs concerning the nature of knowledge and knowing have a crucial effect on the processes and outcomes of thinking. In order to provide a basis for the theoretical framework for studying students' conceptions of scientific thinking the different approaches under the tradition of epistemological beliefs are introduced and compared in this chapter.

The research tradition on epistemological beliefs draws on diverse research approaches. It includes beliefs about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where it resides, and how knowledge occurs (Hofer, 2002). References have included a wide variety of terms, such as epistemic positions (Perry, 1968), epistemic cognition (King & Kitchener, 2002), epistemological reflection (Baxter Magolda, 1992), epistemological understanding (Kuhn et al., 2000) and epistemological thinking (Kuhn & Weinstock, 2002). Hofer and Pintrich (1997) have classified the research of epistemological beliefs and reasoning into the following six issues: a) refining and extending Perry's (1968) developmental sequence; b) developing measurement tools for assessing such development, c) exploring gender-related patterns in knowing; d) examining how epistemological awareness is a part of thinking and reasoning processes; e) identifying dimensions of epistemological beliefs and f) assessing how these beliefs link to other cognitive and motivational processes.

The large area of investigations under the tradition of epistemological beliefs can be categorised as personal epistemology, a field that focuses on exploring how individuals develop their beliefs of knowledge and knowing, and how individuals utilise them in understanding the world. Epistemological beliefs are considered to be a lens through which individuals interpret information, set standards, and decide on an appropriate course of action (Hofer & Pintrich, 2002). This view is widely held among researchers in this field (Pintrich, 2002; Limón, 2006b) and is also adapted as a persective on scientific thinking in my study.

The differences among the current conceptualisations of epistemological beliefs and the methodological problems derived from these differences have influenced Limón's (2006a, 2006b) careful analysis and comparison of different types of epistemological research. Limón's (2006b) categorization, which is based on Hofer's (2004a) conceptualisation, is the following: a) the developmental approach, b) the system of beliefs approach, and c) the epistemological resources approach (see Table 2). The definition of epistemological beliefs as individuals' beliefs about knowledge and knowing in my own study represent the epistemological resources approach. However, in what follows all three approaches and the main characteristics of the models are presented and compared to provide a basis for the theoretical framework of my study.

Table 2. The research tradition of the epistemological beliefs and the central features of approaches within this tradition.

	Research tradition of epistemological beliefs		
	Approaches		
	Developmental approach	**System of beliefs approach**	**Epistemological resources approach**
Central feature of the approach	Describes the develop-mental changes and levels in epistemological beliefs	Describes the nature, features and structure of epistemological beliefs	Describes the contex-tual and domain de-pendent features of epistemological beliefs

2.2.1 The developmental approach of epistemological beliefs

The developmental approach focuses on explaining developmental changes in epistemological beliefs and typically it attempts to describe the developmental levels through which individuals progress. Developmental approaches are typically domain-general models and they assume a high consistency within the development level (Limon, 2006b). Examples of the developmental approaches are Kuhn's (Kuhn at al., 2000; Kuhn & Weinstock, 2002) theory on epistemological thinking, King & Kitchener's (2002) theory of reflective thinking, and Baxter Magolda's (1992, 2004) model of epistemological reflection. A common element for these developmental models is that the primary task of epistemic development is a progression towards the integration of objectivity and subjectivity. It involves learning to coordinate one's own subjective perceptions and meaning making with the facts about 'objective reality' and the knowledge of authorities (Hofer, 2006).

From the historical point of view the most significant name in the field of epistemological development, as well as being a representative of developmental theorists, is Perry (1968). Perry was the first to redefine the way cognition develops, by focusing on the development of epistemological assumptions. Perry and his research team interviewed Harvard undergraduates over their four-year college experience and hypothesised nine developmental positions of intellectual development. These positions in his scheme were clustered into four sequential categories: 1) dualism (the assumption that knowledge is given from outside and that it is absolute), 2) multiplicity (the beginning of the recognition of diversity and uncertainty, all views are equally valid, each person has a right to his or her own opinion), 3) relativism and 4) a commitment to relativism. At the level of relativism individuals make the shift from a dualistic view of the world to a view that encompasses contextual relativism and the major shift at this level is in the perception of the self as an active maker of meaning. Later at this level of relativism individuals begin to realise the need to choose and affirm one's own commitments. The final positions of Perry's scheme are called a 'commitment to relativism'. At this level of development individuals make and affirm commitments for example to values, careers, relationships, and personal identity.

One attempt to clarify the conceptual ambiguity in the area of epistemological development is made by Kuhn and her co-researchers (Kuhn et al., 2000; Kuhn & Weinstock, 2002). They have tried to identify more precisely and exactly what epistemological thinking and its development entail. The aim has been to identify the underlying essence of what is developing in the simplest terms as possible and what are the key elements in the transition from one level to the next. Kuhn and her colleagues (Kuhn et al., 2000) have summarised the key process of epistemological development as follows: the developmental task that underlines the achievement of mature epistemological understanding is the coordination of the subjective and objective dimensions of knowing. Thus, the coordination of subjective and objective dimensions of knowing is the central dimension that drives the progress of epistemological development (Kuhn & Weinstock, 2002). Kuhn and her colleagues (Kuhn et al., 2000) have defined four levels in this development process: realist, absolutist, multiplist and evaluativist. The key issue in their model is a sequence of qualitatively distinct understandings of what it means to make a claim. At the level of realist and absolutist thinking the objective dimension dominates to the exclusion of subjectivity (claims as copies, claims as facts). Then, the subjective dimension assumes an ascendant position and the objective is abandoned (claims are opinions). Finally, both the objective and subjective dimensions are coordinated, with a balance achieved in which neither overpowers the other. That is, at the final level claims are judgments that can be evaluated and compared according to the criteria of argument and evidence (Kuhn et al., 2000). At the final level of development the core of evaluative thinking is the same as in dialectical thinking (Kuhn & Weinstock, 2002). Dialectical thinking in the epistemological context can be defined as a dialectical way of viewing knowledge and reason through oppositional relationships of knowledge (Basseches, 2005).

Some researchers have directed their criticism toward the existing developmental models and questioned the developmental sequence in the approaches which invariably suggest movement from the dualistic, objectivist view of knowledge to a more subjective, relativistic stance, and ultimately to a contextual, constructivist perspective of knowing (e.g., Hofer, 2002; Kallio & Liitos, 2009; Kallio, 2011). According to Kallio and Liitos (Kallio, 2011; Kallio & Liitos, 2009), in the light of the current state of research it is unclear if it is possible to set the thinking models (absolutism-relativism-dialectics) in a hierarchical developmental order. They have asked whether absolutistic assumptions about knowledge represent a lower level of thinking than relativism and dialectical thinking. Or is it possible that these three thinking models are parallel modes of thinking.

There is one further limitation in the developmental models in their description of the development of knowledge and knowing. According to Limón (2006b), there is a lack of clear separation in these models between beliefs (declarative knowledge) and skills (procedural knowledge), and this might generate confusion when these models are applied to evaluate individuals' epistemological beliefs. Epistemological beliefs and the skills needed to reach the stages of the developmental models are two different aspects, although both of them may be necessary to show a particular level of epistemological understanding (Limón, 2006b).

2.2.2 System of beliefs approach

The models included in the system of beliefs approach are focused more on describing the nature, features and structure of epistemological beliefs that are more or less independent of each other. This approach assumes that epistemological beliefs are multidimensional, for an individual may have different beliefs at different dimensions and no coherency or consistency across domains should necessarily be expected (Schommer-Aikins, 2002; Limón, 2006b). The epistemological belief system developed by Schommer (1990; Schommer-Aikins, 2004) and the theory on beliefs about academic knowledge introduced by Buehl and Alexander (2005; 2006) represent the system of beliefs approach. Both these models share the view that as the change proceeds and as a consequence of the contextual effects, personal epistemology will differentiate and shift from domain-general to more domain-specific (Limón, 2006b).

At the beginning of the 1990s Schommer (1990, 1993, Schommer et al, 1992) introduced the idea that personal epistemology should be considered as a system of more or less independent beliefs. Derived from Perry's (1968) and King and Kitchener's earlier research from the 1990s (King & Kitchener, 2002), Schommer developed a belief system which contains five more or less independent dimensions: stability of knowledge, structure of knowledge, source of knowledge, speed of knowledge acquisition and the control of knowledge acquisition/ability to learn. In the later work of Schommer-Aikins (Schommer-Aikins & Easter, 2006) the focus has been widened to include the dimension of ways of knowing. Epistemological beliefs do not develop in synchrony. This means that there are times during development that an individual may believe that knowledge is highly complex, yet simultaneously believe that knowledge is highly certain. The key here is that this synchrony or asynchrony will vary depending on the stage of development the individual has reached. According to Schommer-Aikins (2002), the same is true with regard to the domain specificity issue. As the learners progress in their development they will acquire both domain-specific and domain-general epistemological beliefs. Depending on where the individual is developmentally, his/her personal epistemological beliefs may be predominantly domain-general or domain-specific. In addition, Schommer-Aikins (2002) considers that all individuals have a general core of epistemological beliefs which may serve as the foundation from where their domain-specific epistemological beliefs originate. This general core of epistemological beliefs will also serve individuals when they are initially learning a new domain, that is when one cannot readily relate the new domain to a domain which is already familiar (Schommer-Aikins, 2002). In Schommer-Aikins' (2002) opinion the development of epistemological beliefs is a recursive, life-long process of revisiting, revising, and honing the beliefs within a system of epistemological beliefs.

2.2.3 The epistemological resources approach

The epistemological resources approach includes research and theoretical frameworks which, compared to two other approaches, have different assumptions concerning the development process and the role of contextual factors in epistemological beliefs (e.g., Hofer & Pintrich, 1997; Hammer & Elby, 2002; Louca, Elby, Hammer & Kagey, 2004). The epistemological resources approach underlines the role of epistemological resources, which become richer as the individual gains more knowledge and experience with learning (Louca et al., 2004). Individuals have a host of epistemological resources available to them as learners, and the context affects what might be evoked (Hofer, 2004a). Epistemological resources are considered to be both domain- and context-dependent (Louca et al., 2004; Limón, 2006b). It is less sensitive to the cognitive developmental assumptions that underlie other models but it is more attuned to contextual variables (Hofer, 2004a).

According to the epistemological resources approach, belief development will not follow a stage model and ladder path, but rather a web of developmental pathways (Hofer, 2001). Hofer (2005) sees the development of personal epistemology as a cyclical process, not linear or stage-like. Further she has argued that epistemological growth occurs in multidimensional ways, including regression and recurrent thinking.

The most remarkable theory arising from the epistemological resources approach has been Hofer's and Pintrich's (1997) theory of personal epistemology. Hofer and Pintrich (1997, Hofer 2000; 2004b) have argued that epistemic development (personal epistemology) should be restricted to dimensions which concern the nature of knowledge and the process of knowing. Thus, beliefs of learning and knowledge acquisition (Schommer, 1990; Schommer & Walker, 1995) are excluded from the framework and emphasis is on questions which concern knowledge and knowing. Within the selected framework, Hofer & Pintrich (1997) have described four dimensions of epistemic beliefs: certainty of knowledge, simplicity of knowledge, source of knowledge and justification for knowing (Hofer & Pintrich, 1997). The development of each dimension can be expressed as a continuum. The term 'dimension' refers to the componential nature of epistemic development and beliefs. Beliefs are organised into theories, instead of being a system of independent beliefs, and they operate at the metacognitive level (Hofer & Pintrich, 1997; Hofer, 2004a). This multidimensional aspect of beliefs has been an outstanding feature of research for the last fifteen years and has been adopted by several researchers (Hofer & Pintrich, 1997; Hofer, 2006; Schommer, 1990; Buehl & Alexander, 2006; Buehl & Alexander, 2005; Strømsø, Bråten & Samuelstuen, 2008).

One of the most-discussed issues concerns the nature of personal epistemology as domain-general and/or domain-specific (Muis, Bendixen, Haerle, 2006; Limón, 2006b). The question in this discussion has been the degree to which an individual holds similar epistemological beliefs across different domains. Domain is typically defined in the context of epistemological research as a discipline, an academic domain but also as a judgment domain involving personal taste, morality and meaning (e.g. Kuhn et al., 2000). Some researches have supported the assumption that epistemological changes occur evenly across all disciplines and that the general nature of personal epistemology is domain-general (e.g. Perry, 1968; Kuhn et al., 2000; Kuhn & Weinstock, 2002; King & Kitchener, 2002). In addition there are researchers who propose that personal epistemology may include both domain-general and domain-specific beliefs (e.g., Buehl, Alexander & Murphy, 2002; Buehl & Alexander, 2001; Muis et al., 2006; Hofer, 2000, 2006; Ylijoki, 2000; Louca et al., 2004; Lindblom-Ylänne et al, 2006). The theories of Hofer and Pintrich (1997, 2002) represent the latter approach and assume that domain-general and domain-specific epistemological beliefs may coexist and that these beliefs are activated by context (both school and out-of-school context variables such as pedagogical practices, assessment methods, curriculum, teachers' and peers' expectations and culture). According to Hofer (2006), individuals hold beliefs about knowledge and knowing that are coherent and congruent, but also hold beliefs that are affected by and enacted within particular contexts. The theory also includes an assumption that epistemological beliefs develop from the general to the specific over time and in relation to education and experience (Hofer, 2006). This view of development is widely shared by many researches representing a variety of different approaches (Muis et al., 2006).

2.3 The connections between the two traditions of scientific thinking

The connections between epistemological beliefs and other cognitive skills have been the focus of several researches. However, published research investigating the exact connections between epistemological beliefs and logical reasoning skills or formal operations is rare. Instead, some examples of the research concerning the interaction between epistemological beliefs and other higher order thinking skills, which share cognitive elements with logical reasoning, are presented in this chapter.

One of the first authors who explored the connections between epistemological beliefs and other forms of cognitive operations was Ryan (1984a, 1984b). Ryan was interested in how epistemological beliefs may affect comprehension (comprehension was assessed using Bloom's Taxonomy[7], see Biggs & Collins, 1982) and academic performance in college student. Ryan hypothesised that transition from dualism to relativism (movement from a conception of knowledge as discrete facts to a conception of knowledge as interrelated propositions) would be linked with changes in information-processing strategies. The research result was that epistemological beliefs had an impact on the effectiveness of one's text-processing efforts, the learning process and also indirectly on academic performance (Ryan 1984a, 1984b). Perry (1981) has also speculated on possible connections between cognitive styles, learning strategies and development. Perry hypothesised that changes in students' views

[7] Bloom's Taxonomy is a systematic way of describing how a learner's performance develops from simple to complex levels in affective, psychomotor and cognitive domain of learning. In cognitive domain, there are six stages, namely: knowledge, comprehension, application, analysis, synthesis and evaluation (Biggs & Collins, 1982).

on the nature of knowledge and the role of authority will lead to changes in the manner of studying, shown in altered modes of learning and cognition (ibid.).

The reflective judgement model by King and Kitchener (King and Kitchener, 1994; 2002; 2004; Kitchener et al., 2006) encompasses both personal epistemology and the skills of critical thinking and it is grounded in more than twenty years of research. The model has been strongly influenced by Perry's model. Kitchener (1983) has also studied cognitive processes that are involved in epistemic thinking (the processes of justifying knowledge). According to his view these processes are cognitive processes of a higher level than simple inductive reasoning or general critical thinking.

In Kuhn's (1991) studies the focus has been on the links between the level of epistemological understanding individuals possess and the kinds of thinking they display. The results of these studies indicate connections between adults' argumentative reasoning skills and epistemological understanding: subjects who possess an evaluativist attitude towards arguments are more likely than others to exhibit the argumentative skills of counterargument and to generatate alternative theories. Argumentative skills appear to be predicted on a level of epistemological understanding that requires contemplation, evaluation and judgment of alternative theories and evidence. At this level of evaluative epistemology, individuals are most likely to see the value of argument and the need for comparing and evaluating alternative claims. According to Kuhn (1991), these cognitive processes require the metacognitive ability of being reflective about one's own thinking.

Schommer (1990, 1993, Schommer et al, 1992) has explored how epistemological beliefs influence comprehension and academic performance, and Kardash & Howell (2000) have studied how beliefs about the nature of knowledge may influence cognitive processing and strategy deployment. All these studies (Schommer, 1990, 1993; Schommer et al, 1992; Kardash & Howell (2000) have revealed the relation between beliefs about knowledge, strategy use and performance: epistemological beliefs may have an indirect effect on academic performance, as belief about knowledge may affect study strategies (in Schommer's studies beliefs in quick learning, simple knowledge and certain knowledge all predicted poor performance).

Muis (2008) has examined the relations between epistemic profiles, the regulation of cognition and problem solving in mathematics. Her results suggest that epistemic beliefs are related to self-regulated learning and achievement. The dimensions of epistemological beliefs as predictors of multiple text understanding have been studied by Strømsø and colleagues (Strømsø et al., 2008). The results indicate positive associations between the dimensions of simplicity and certainty of knowledge and deep understanding of texts. However, the belief that the knower is an active constructor of meaning (source of knowledge) negatively predicted deeper understanding.

Weinstock (2009) has explored the relationship between the epistemic construal of a specific everyday reasoning task with performance on the task and the general epistemological understanding of knowledge construction and evaluation (participants were adults, serving jury duty, ages 19-73). His expectation is that epistemological understandings influence how people reason about and construct new knowledge. Epistemological understanding is seen to consist of four dimensions of the nature of knowledge and knowing: the certainty, simplicity, source, and justification of knowledge (as proposed by Hofer & Pintrich, 1997). The development of epistemological understanding is seen to progress from the absolutist and multiplist levels to the evaluativist level (following Kuhn, 1991). The results of Weinstock's (2009) studies showed that how people characterize experts' reasoning affected the way in which they themselves reasoned. That is, how one thinks an expert would perform a task may well guide one's actual performance in the task. The results showed that people with more sophisticated conceptions of what a competent reasoner must do to create sound knowledge claims argued with greater skill and attention to the complexity of arguments. These research results are related to Wellman's (1990) theory of mind (an individual's personal theory of epistemology). The hypothesis of this theory is that epistemological beliefs are an individual's theories about the nature of knowledge and the processes of thinking. According to Wellman's research it does appear that if an individual makes an ontological commitment to a particular stance regarding the certainty of knowledge (i.e. absolutist versus relativistic), then he/she will perceive and think about his/her experience in a certain manner.

As the examples of research approaches and Table 3 show, a positive interaction between the development of epistemological beliefs and other cognitive skill, learning strategies and approaches has been proved to exist. However, the research on the connections between epistemological beliefs and logical thinking has being lacking.

Table 3. Research on the connections between epistemological beliefs and other cognitive skills.

Author(s)	**Cognitive skills, which are connected to epistemological development**
Ryan (1984a, 1984b)	Text processing, learning process and academic performance
Perry (1981)	Cognitive styles and learning strategies
Kitchener (1983)	Cognitive processes of reasoning ability
King and Kitchener (2002; 2004); Kitchener and colleagues (Kitchener et al., 2006)	Critical thinking
Kuhn (1991)	Argumentative reasoning skills and metacognitive thinking
Schommer (1990, 1993); Schommer and colleagues (Schommer, Crouse & Rhodes, 1992; Schommer-Aikins & Easter, 2006); Kardash & Howell, 2000)	Use of study strategies and academic performance
Muis (2008)	Regulation of cognition and mathematical problem solving
Stømsø and colleagues (Stømsø et al., 2008)	Text understanding
Weinstock (2009)	Knowledge construction and evaluation

2.4 Discipline-specific effects on scientific thinking

Students' epistemological beliefs on knowledge and knowing are influenced by their learning environment and academic context, where the values, aims, academic culture, knowledge structures and epistemological assumptions affect their ways of thinking.

According to Muis and his colleagues (Muis et al., 2006), personal epistemology is complex and socially constructed; that is, individuals actively construct or make meaning of their experiences, and development occurs as a function of one's interactions with the social world (see also e.g., (Baxter Magolda, 2004; Bendixen & Rule, 2004; Hofer & Pintrich, 1997). In the research, the effects of epistemological beliefs and differences between the disciplines are analysed from different perspectives: classification of the disciplines on the base of cultural and epistemological differences (Biglan, 1973a; Becher, 1994), differences between the disciplines in the nature of teaching (i.e. teaching practices, outcomes) (e.g., Becher & Trowler, 2001, Neumann, 2001; Neumann et al., 2002; Lueddeke, 2003; Lindblom-Ylänne et al., 2006), disciplinary values, knowledge validation and cognitive goals related to students' learning (e.g., Neumann, 2001; Ylijoki, 2000; Neumann et al., 2002; Palmer & Marra, 2004; Buehl & Alexander, 2001, 2006; Hofer, 2000) and also disciplinary differences in the students' approaches to learning (e.g., Entwistle & Ramsden, 1983; Lonka & Lindblom-Ylänne, 1996; Smith & Miller, 2005; Parpala, Lindblom-Ylänne, Komulainen, Litmanen & Hirsto, 2010).

Values, epistemological beliefs and aspects of the learning environment in the field of business and administration

Cultural and epistemological differences have been used as a basis of classification of disciplines in Biglan's (1973a, 1973b) model. Becher (1994) has continued the work and indentified four main intellectual clusters/ categories of disciplines: 'hard pure', 'soft pure', 'hard applied' and 'soft applied'. Disciplinary groups can be regarded as academic tribes, with their own set of intellectual values and own categories of thought, which provide shared concepts, methods, techniques and problems (Becher & Trowler, 2001; Ylijoki, 2000). Becher (1994) considers that the cultural aspects of disciplines and their cognitive aspects (conceptions of knowledge and methods in the fields) are intertwined and has presented a framework which includes the four knowledge domains and associated disciplinary cultures. He has grouped the disciplines and the nature of knowledge in these disciplines into four groups: pure sciences (e.g. physics) - hard pure; humanities (e.g. history) and pure social sciences (e.g. anthropology) - soft pure; technologies (e.g. mechanical engineering) - hard applied; and applied social sciences (e.g. education) - soft applied. Becher (ibid.) has given some examples of disciplines in the different categories, but has not placed economics and business administration in any category. He also acknowledges that the classification is not complete and a number of exceptions can be found: a given discipline may straddle two categories and occasional disciplines may change categories over time. In Biglan's work (1973a), accounting, finance and economics is placed in the category of soft-applied. Later, Smith and Miller (2005) have categorised business-related disciplines (economics and computing) as hard-applied. In my study the field of business and administration is considered to include the characteristics of both hard-applied and soft-applied categories.

Becher (1994) has characterised the hard-applied culture in the following way: purposive, pragmatic (know-how via hard knowledge), entrepreneurial, dominated by professional values and role oriented. Soft applied culture is characterised as functional, utilitarian (know-how via soft knowledge), concerned with the enhancement of professional practice, resulting in protocols/procedures, outward-looking, uncertain in status, power-oriented.

As Muis and colleagues (Muis et al., 2006) have stated, in the development of epistemological beliefs larger sociocultural contexts influence smaller academic contexts, which in turn influence instructional environment and contexts, educational policies and practices. The acquisition of epistemic beliefs occurs through a process of enculturation; students learn to view knowledge from the same perspective as those around them (ibid.). These contextual disciplinary differences from the perspective of teaching and learning is analysed, for example, by Neumann (2001), Neumann and colleagues (Neumann et al., 2002); Lueddeke (2003); Lindblom-Ylänne and colleagues (Lindblom-

Ylänne et al., 2006) and the connections between disciplines and basic beliefs, values, norms of the local culture, for example by Ylijoki (2000). In the work of Neumann and colleagues (Neumann et al., 2002) the focus has been on teaching and learning and within that framework the disciplines have been characterised in differentiation from each other. The underlying assumption in their work has been that the process of validation varies across disciplines as the criteria and process itself depends on the methods used or the processes of thinking. Neumann and colleagues (ibid.) have used the existing research results (e.g. Ballantyne, Bain & Packer, 1999; Kolb, 1981) in their analysis of the typical characteristics of the disciplines. The analysis covers, for example, the following perspectives: the curriculum, the main cognitive purpose in the field, and the implicit requirements of students. The analysis provides information on both hard and applied disciplines. In these two dimensions of the disciplines the field of economics and business administration can be categorised as an applied discipline. According to the analysis, one contrast between the hard and applied disciplines is in the knowledge validating process: in applied fields the knowledge validation process relies less than pure counterparts on examining conflicting evidence and exploring alternative explanations and does not depend so much on precision and accuracy as criteria in validating knowledge (Neumann et al., 2002). The results of Ylijoki (2000) are in line with this: in the hard sciences there are more clear criteria for knowledge justification, whereas in the soft sciences the criteria are more situational and tied to the context of thinking (Ylijoki, 2000). Applied disciplines - both hard and soft - have a different profile concerning cognitive aims and student requirements on account of the strong value placed on the integration and application of existing knowledge. In hard applied fields great emphasis is placed on practical competencies and on the ability to apply theoretical ideas to professional contexts. Students need to be able to organise knowledge in such a way that, through hypothetical-deductive reasoning, they can focus it on specific problems. Students in soft applied sciences are also called upon to exercise problem-solving abilities, though of a more open-ended variety. Both hard and soft applied disciplines and programmes have the vocational nature of the programmes in common (Neumann et al., 2002).

A consistent body of research results also exists that has demonstrated the interaction of students' epistemological beliefs with the disciplinary environment (i.e. with the characteristics of the curriculum and the nature of the discipline) (Palmer&Marra 2004; Schraw & Sinatra 2004). Researchers have found that students' personal epistemology in different disciplines is rather similar at the beginning of their studies and the divergence increases as the studies progress and as a result of dissimilarity of the curricula and disciplinary culture (Lindblom-Ylänne, 1999; Ylijoki, 2000; Becher & Trowler, 2001; Kaartinen-Koutaniemi & Lindblom-Ylänne, 2008, see also Muis et al., 2006).

The work of Hammer and colleagues (e.g., Hammer & Elby, 2002; Louca et al., 2004) also provides an example of the power of the learning environment in epistemic development. Their studies show that epistemological advancement might be even more associated with the changing nature of classroom contexts than an individual's cognitive level (Louca et al., 2004).

2.5 Summary of chapter two

The theoretical foundation of this study contains four parts. First, two research traditions of scientific thinking were presented: logical thinking skills and epistemological beliefs on knowledge and knowing. Then, the connections in the research literature between the two traditions were reviewed. Finally, the discipline- and sector- related factors affecting students' scientific thinking were discussed.

Thoretical framework for investigating logical thinking

As stated above, the perspective adopted for this study contains two approaches to scientific thinking of which the first is logical thinking. Research in the area of thinking operations and logical thinking has long traditions starting from Piaget's and Inhelder's development theories in the 1950s. The research area has been developed since then and new development levels alongside of and after the formal operational stage have been defined (Fischer, 1980; Fischer et al., 2003; Lawson et al., 2007; Commons & Richards, 1984a, 1984b; Commons & Bresette, 2006). New theories suggesting post-formal level thinking have aimed to respond to critics concerning the conceptual, empirical and philosophical limitations of the original Piagetian theory. However, a problematic aspect of post-formal models of thinking is that the emphasis of the models is not purely on logical operations of thinking (see Kallio, 2011). Instead, the models are constructed by combining the research traditions of logical operational thinking and epistemological development. Unlike the models of the development of logical thinking, most so-called 'post-formal models' emphasise dialectical epistemology and an epistemology of relativity including elements such as dialectical operations, problem finding, logical relativism, contextualism, self-reference, and the acceptance of contradiction (Marchand, 2001, see also Marchand, 2012).

There are also other aspects affecting the framework and definitions of scientific thinking in this study, which are related to the problematics of using post-formal thinking models. Kallio and Liitos (2009) have argued that at least a part of post-formal type thinking constructs can be seen as integrated or linked to formal thinking (see also Kallio, 2011). It is also possible to see these post-formal-type constructs as parallel to or preceeding formal thinking (Kallio & Liitos, 2009). The post-formal stage may constitute a form of cognition parallel to formal thought, albeit with a practical, contextual and meta-reflective character (Laurenco & Machado, 1996). Also the point of criticism of Marchand's (2001) analysis is the assumption of the developmental sequence of formal and post-formal thinking: post-formal theories assume that acceptance of contradiction and its integration into inclusive systems would be possible only after the stage of formal operations. According to Marchand's (2001) analysis (and referring to Inhelder & Piaget's original texts, 1958) these operations would already be possible at the consolidated stage of formal operations, when subjects need to be able to confront contradictory situations and also integrate the contradiction. Based on the statement of Kramer (1983), Marchand (2001) reminds us that there is not enough empirical research to confirm that formal operations are insufficient for co-ordinating the different references, nor that this co-ordination even represents a structural development beyond formal operations.

The lack of theoretical and conceptual clarity concerning the post-formal models supports the role and significance of formal operational thinking in describing the elementary skills of scientific thinking. Thus, in my study the focus is on logical thinking at the formal operational stage. In logical thinking the hypothetico-deductive causal reasoning process is the key element. That process includes the following sub-reasoning patterns: a) exclusion and control of variables, b) constructing and using formal models, and c) logical reasoning (Inhelder & Piaget, 1958; see also Adey & Shayer, 1994 and Kallio, 1998). The importance of these reasoning patterns is in their ability to isolate the factors which may possibly have an effect on an outcome, to consider each of them in turn and all together, and to make a rational assessment of their relative contributions to the overall effect. In other words, the focus is on these three causal reasoning schemata, which can be seen as the necessary and relevant basis for coordinating the effects of one or several variables in an outcome. Other schemata at the formal operational level are not included in the framework of this study. Similarly, other areas of adult psychological and cognitive development (e.g., socio-cognitive development and emotions), which are included in several post-formal models, are outside the scope of this study.

The other element included in students' logical thinking skills is the reflection on, and monitoring and management of, one's thought. Metacognitive awareness of the reasoning process (metapresentation) and the ability to analyse and integrate thought processes enhance understanding and problem-solving efficiency (Demetriou & Kazi, 2006; Demetriou et al., 2011). Metacognition is defined in this study as a student's ability to specify the thought processes, reflect on, analyse, and contrast the processes, as well as define the similarities and differences between the thought processes evoked by them (Demetriou & Efklides, 1985). In my study the development of the metacognitive awareness of logical thinking processes is analysed according the Demetriou and Efklides's model, which includes the following levels: (i) the level of no conscious reflection, (ii) the level of content-based reflection, (iii) specification of the cognitive operations involved, and (iv) analysis and integration of cognitive operations (Demetriou & Efklides, 1985; Demetriou, 1990). In the context of this study the metacognitive awareness of reasoning processes is explored as an ability which is related to formal operational thinking, and is not defined as representing the stage of post-formal thinking.

Theoretical framework for investigating students' epistemological beliefs

The research tradition of epistemological beliefs provides this study with a framework for studying students' conceptions of scientific thinking. Conceptions of scientific thinking are epistemological beliefs on knowledge and knowing. The research tradition on epistemological beliefs aims to understand how individuals develop conceptions of knowledge and knowing and utilise them in understanding the world (Hofer, 2006). The tradition of epistemological beliefs includes different approaches: some of them attempt to explain developmental changes and to describe the developmental stages through which individuals proceed, and some are focused more on describing the nature and structure of more or less independent epistemological beliefs (Hofer, 2004a; Limon, 2006b). The theoretical framework of investigating students' conceptions of scientific thinking in this study is based on the main principles of Hofer and Pintrich's (1997) theory on personal epistemology. The approach underlines the nature of beliefs as epistemological resources. The theory of personal epistemology include the following three main assumptions of the nature of epistemological beliefs which are also suitable for exploring conceptions of scientific thinking: 1) epistemological development is a cyclical process that occurs in multidimensional ways and is not stage-like (Hofer, 2005), 2) contextual and domain-dependent features of epistemological resources have an effect on epistemological beliefs (see e.g., Hofer, 2006; Buehl & Alexander 2006; Louca et al., 2004; and Muis et al., 2006), and 3) epistemological beliefs develop from the general to the specific over time and in relation to education and experience (Hofer, 2006, Muis et al., 2006).

In my study students' conceptions of scientific thinking are analysed from the point of view of subjective and objective approaches to thinking and knowing, and through the four dimensions of epistemological beliefs: a) certainty of knowledge, b) simplicity of knowledge, c) source of knowledge and d) justification for knowing (Hofer & Pintrich, 1997; Hofer, 2002, 2004a).[8] The

[8] Another multidimensional belief theory that includes similar components have been suggested by e.g. Schommer and her co-researchers (Schommer 1990; Schommer & Walker, 1995; Schommer-Aikins, 2002), who have developed the epistemological belief system theory. The three corresponding dimensions between the models are the structure of knowledge (is knowledge simple and isolated or complex and integrated?), the stability of knowledge (is knowledge certain

descriptions of the development of each dimension presented by Strømsø, Bråten and Samuelstuen (2008) are applied in the analysis of the students' conceptions. The model of Strømsø and his colleagues, which include the descriptions of development expressed as a continuum from less sophisticated to more sophisticated beliefs, is based on Hofer and Pintrich's theory of the dimensions of beliefs (Hofer & Pintrich, 1997) (see Table 4.).

Table 4. Dimensions of epistemological beliefs, which are applied in this study in exploring students' conceptions of scientific thinking (Strømsø et al., 2008).

Dimension of epistemic belief	Less sophisticated epistemological beliefs	More sophisticated epistemological beliefs
a) Certainty of knowledge	Knowledge is certain, absolute and unchanging	Knowledge is tentative and evolving
b) Simplicity of knowledge	Knowledge consists of more or less isolated facts (knowledge consists of a loose collection of proven facts)	Knowledge consists of highly inter-related concepts (knowledge is theoretical and complex)
c) Source of knowledge	Knowledge is transmitted from external authority	Knowledge is actively constructed by individuals in interaction with the environment (personal judgments and interpretations)
d) Justification for knowing	Justification through observation, authority, or what feels right (rejection of the notion that knowledge claims need to be checked against reason or other sources)	Justification through the use of rules of inquiry and the evaluation and integration of multiple sources (evaluation through independent, critical and logical thinking, as well as through the comparison of multiple related sources)

The frame of reference for investigating students' scientific thinking is summarised in Figure 3, which visualises the understanding of the two approaches of scientific thinking as well as the contextual factors which affect students' thinking skills.

or tentative?) and the sources of knowledge (does knowledge originate from an external source or from personal experience?). The source dimension also involves a resemblance to the key element in Kuhn's (Kuhn et al., 2000) model of the development of epistemological understanding.

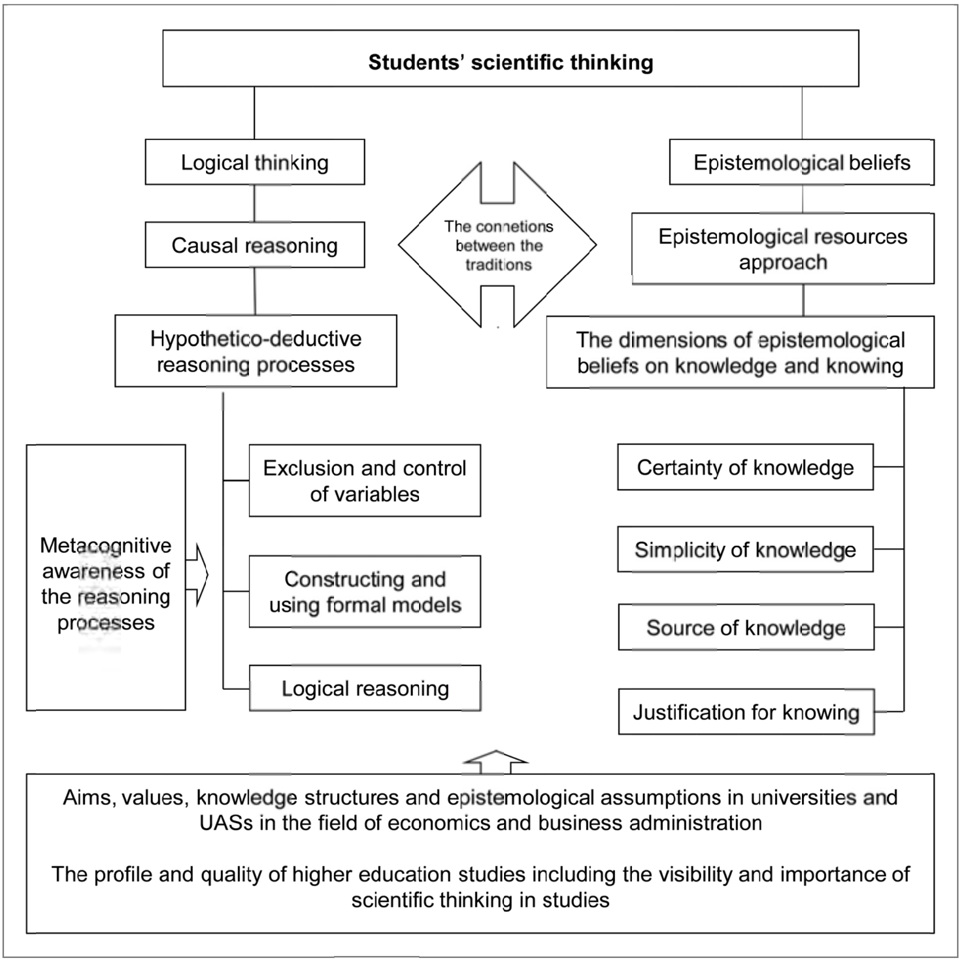

Figure 3. The theoretical framework for studying students' scientific thinking.

3 RESEARCH METHODS

This study includes two sub studies: i) the study of students' logical thinking skills and metacognitive awaress of the reasoning prosesses and ii) the study of students' conceptions of scientific thinking including the study of students' experiences of thinking and learning in higher education studies in the two sectors. In the following sub chapters the measures, reliability and validity analysis and descriptive characteristics of the subjects within these studies are described.

3.1 Study of the logical thinking skills and the metacognitive awareness of reasoning

3.1.1 Descriptive characteristics of the study subjects

338 business major students from nine higher education institutions participated in the study of logical thinking (Pendulum task n= 334, Chemicals task n=336) and metacognitive awareness (Comparison task n=322). The following four universities and five universities of applied sciences (UAS) participated in the study: Joensuu University (since 2010, University of Eastern Finland), University of Kuopio (since 2010, University of Eastern Finland), Lappeenranta University of Technology, Turku School of Economics (since 2011, University of Turku), EVTEK Polytechnic (since 2005, Metropolia University of Applied Sciences), HAAGA-HELIA University of Applied Sciences, Laurea University of Applied Sciences, Kymenlaakso University of Applied Sciences, and Turku University of Applied Sciences. Ten higher education institutions were given the offer to participate in the study of which one university declined. In total there are 9 universities and 28 UASs in Finland offering an economics and business administration degree education. Institutions for this study were selected on a volunteer basis. Another criteria in selection was the institutions' geographical location (offering good opportunities to arrange data collection). The data was collected between 1 October 2002 - 10 April 2004. Students participated in the study in these selected higher education institutes on a volunteer basis and they had an opportunity to get their personal results and the means of the scores of their own study groups after the tests by e-mail. Students were divided into three groups by using the number of their study credits as criteria. At the time of data collection (years 2002-2004) the length of the university Master's degree in the field of business education was 160 credit units, and the length of the UAS

Bachelor's degree was 140 credit units.[9] The three student groups used in this study were constructed as follows:

- Initial phase of studies: 1- 50 study credits
- Intermediate phase of studies: 51-100 study credits
- Final phase of studies over 100 study credits

In the sample the number of women was 66.8% (n=225). In the university sector the proportion of female students in this study was 58.5% (n=86) and among the UAS students 73.2% (n=140). In 2003 the proportion of female students of all new university students in the field of business was 45.6% (KOTA database, 2003) and in UASs the proportion of female students was 69.3% (AMKOTA database, 2003). In the university sector the consistency of the gender distribution between the sample and the population was significant (χ^2 (1)=6.673, p<.01).

Students' age varied from 19 to 47 (M= 23,25, SD=4,98). 79% of the students were under 25 years of age. University students were on average two years younger than the UAS students. The age distribution in this study and among all business and administration students in the UASs in 2003 (AMKOTA database, 2003) was significantly consistent (χ^2 (6)=69.667, p<.001). The information of students' age distribution covering all universities providing business education was not available.

[9] The credit unit system has been changed after conducting the data collection of this research. The system was renewed in 2005 as part of the higher education degree reform in Finland. According to the current system, studies are quantified as credits (ECTS). The University Bachelor's-level degree requires 180 credits (three years full-time study). The Master's degree is a further 120 credits (two years of full-time study on top of the Bachelors' degree). The UAS Bachelor's degree studies generally requires 210−240 study credits (ECTS), which means 3.5 - 4 years of full-time study.

Table 5. Age, gender, number of study credits and years of studies of students at the initial, intermediate and final phase of studies in UASs and universities.

* Information on gender was available for 337 students

Higher education sector	Phase of studies	N	Age		Gender*		Study credits		Years of studies	
			M	SD	Female	Male	M	SD	M	SD
UAS	**Initial phase**	120	20.9	2.7	89	30	25.7	10.3	1.03	.21
	Intermediate phase	29	22.8	2.1	16	13	79.2	10.8	2.21	.73
	Final phase	42	28.7	6.9	34	8	131.5	10.8	3.24	.85
	Total	191	22.8	5.0	139	51	45.4	35.7	1.69	1.05
University	**Initial phase**	52	22.5	5.4	29	23	33.3	12.6	1.15	.36
	Intermediate phase	32	23.8	5.5	15	17	81.3	12.3	2.25	1.05
	Final phase	63	24.9	4.0	42	21	142.2	31.2	3.79	1.32
	Total	147	23.9	5.0	86	61	90.4	53.3	2.52	1.55
Total		338	23.3	5.0	225	112	71.6	51.5	2.06	1.37

Information on students' prior education (completed before the current higher education studies) was available for only 274 students. According to the national UAS database (AMKOTA database, 2003) the distribution of the UAS students' prior education in the field of business and administration was the following: matriculation examination 73.1%, upper secondary vocational education 18.9%, UAS Bachelor's degree 4.1% and some other prior education 3.9%. There is a significant connection of the distributions of the UAS students' prior education in this study and in the population (χ^2 (3)=13.692, p<.01). The prior education information of university students in the educational field of business studies was not available.

Table 6. UAS students' and university students' prior education in the initial, intermediate and final phase groups.

Higher education sector	Phase of studies	N	Prior education				
			Matriculation examination	Upper secondary vocational education	Matriculation examination + vocational education	Bachelor's (UAS degree)	Bachelor's/Master's/ Licentiate (university degree)
UAS	Initial phase	109	99	6	3	1	0
	Intermediate phase	25	20	2	1	1	1
	Final phase	25	11	6	8	0	0
	Total	159	130	14	12	2	1
University	Initial phase	39	29	3	3	4	0
	Intermediate phase	29	22	2	3	2	0
	Final phase	47	33	0	2	7	5
	Total	115	84	5	8	13	5
Total		274	214	19	20	15	6

3.1.2 Measures of logical thinking and the metacognitive awareness of reasoning processes

Three measures were used to find out students' logical thinking skills and the differences in these skills between the different research groups in universities and UASs: Science Reasoning Tasks (SRT) called the Pendulum (Shayer, Wylam, Kuchemann & Adey, 1978, see Kallio 1998); the Chemicals task (ibid.) for measuring formal reasoning; and the Comparison task (CT) (Demetriou & Efklides, 1985; Kallio, 1998) for measuring the metacognitive awareness of formal operational schemata. Students answered the tasks in this order and they took in all about two hours to answer. Finnish versions of all the tasks were used. The tasks were arranged in groups of 5-40 economics and business administration major students (in universities)/business administration students (in UASs) in four universities and five universities of applied sciences. I personally scored the answers of the Pendulum, Chemicals and Comparison tasks with the help of a research assistant.

The Pendulum task

The task consisted of nineteen items and was divided into two parts. Four experiments using a pendulum were showed in the video where the experiments differed from each other in the combinations of three variables (i.e. swing, weight and push). Based on the given experiments, the subjects had to conclude which kind of causal effect each variable had on the number of swings the pendulum made in half a minute. One point was given for every correct answer using the scoring rules. The points were counted together as the total score, which corresponded to a number on a scale expressing the developmental stage (scale constructed using Rasch scaling, see Adey & Shayer, 1994 and Kallio, 1998). The developmental stages ranged from 'full concrete operational' (2B) to 'formal generalization' (3B*) (see Table 7) (Shayer, Wylam, Kuchemann & Adey, 1978, see Kallio, 1998). See Appendix 1 for the task sheet; Appendix 2 for scoring rules and Appendix 3 for developmental stages according to the scores.

The Chemicals task

The task used Shayer's version (1978), which has also been used in Kallio's (1998) research on university students' scientific reasoning skills. The experiments with chemicals were performed in the video, and the subjects had to answer nineteen questions relating to the experiments. The subjects had to deduce from the given data and the experiments shown, which of the chemicals had a causal effect on colourformation in mixing the liquids. The scoring and scaling of the developmental stages was technically similar to the Pendulum task. The range of developmental stages was from 'mid concrete operational' (2AB) to 'formal generalization' (3B*) (Table 7.). See Appendix 4 for the task sheet; Appendix 5 for scoring rules and Appendix 6 for the developmental stages according to the scores.

The Pendulum and the Chemicals tasks were both used in this study to indicate the students' developmental stages of logical thinking at the level of formal operations. However, because of the slightly different emphasis and foci of these tasks they were analysed as parallel indicators of students' reasoning skills and were not combined into one measure. The Pendulum task measures primarily the schema of handling of variables (control and exclusion of variables), whereas the Chemicals task also focuses on formal models (logical deduction from the given premises and constructing and using formal models).

The Comparison task of the Pendulum and the Chemicals tasks

The task was constructed in a similar way to Demetriou and Efklides' (1985, Kallio, 1998) 'metacognitive' task (see also Kallio, 1998). The task consisted of two open questions in which subjects have to compare the Pendulum and the

Chemicals task and evaluate the task properties and analyse their own thoughts processes during the task answering. The analysis of the students' answers focused on the manifest content of the answers (what the text says, instead of an analysis of the latent content, what the text talks) (see, e.g., Graneheim & Lundman, 2004). Students' answers were categorised into six levels, from 'level of no reflection' to the 'level of specific analysis and integration' (Table 7) (Kallio, 1998). See Appendix 7 for the task sheet; Appendix 8 for the scoring rules.

Table 7. Developmental ranges of the tasks used.

Pendulum and Chemicals tasks

Developmental stage	Symbol	Score
Early concrete reasoning	2A	1
Mid concrete reasoning	2AB	2
Full concrete operational	2B	3
Concrete generalisation	2B*	4
Early formal operational	3A	5
Full formal operational	3AB	6
Formal generalisation	3B*	7

Comparison task

Levels	Score
Level of no reflection	1
Level of reflection of the content of the task	2
Level of developing general analysis	3
Level of general analysis	4
Level of developing specific analysis and integration	5
Level of specific analysis and integration	6

Lowest levels of metacognitive development, 1-2

Intermediate levels representing a general-analysis level of metacognitive awareness, 3-4

Highest levels of metacognitive awareness, 5-6

3.1.3 Reliability of the tasks

The answers of 50 students were randomly selected for the reliability analysis of the Pendulum and Chemicals tasks. The internal consistencies using Cronbach's alpha coefficient were .77 for the Pendulum and .71 for the Chemicals task. In the research of Shayer and Adey (1981, see Kallio 1998) the internal consistency using an alpha coefficient of KR20 was .83 in the Pendulum task and .76 in the Chemicals task. Kallio (1998) reports an alpha coefficient of KR20 .81 for the Pendulum and .53 for the Chemicals task. Shayer and Adey (1981) also report a test-retest correlation: with the Pendulum .79 and with the Chemicals task .64. The item-intercorrelations of the tasks were also used as an indicator of inner coherence. In this study the intercorrelations (Kendall's tau-b) of the items varied from -.35 to .82. for the Pendulum task and from -.24 to .90 for the Chemicals task. Kallio (1998) has reported the intercorrelations for the Pendulum from -.07 to .85 and for the Chemicals task from -.14 to .68.

In this study the task-intercorrelation (Kendall's tau-b) between the Pendulum and the Chemicals tasks was .19 (p<.001). The intercorrelation of the tasks in Kallio's (1998) research was .22. The interconnection of the students' scores in this research in the Pendulum and in the Chemicals tasks is presented in Table 8. 81.3% (n=270) of the students showed either concrete generalisation, 2B*, (transformation stage) or formal operational (3A-3B*) both in the Pendulum and in the Chemicals tasks. Six students were classified at the levels of early concrete reasoning or mid concrete reasoning (2AB-2B) in both tasks. 9.0% (n=30) of the students showed concrete generalisation or formal operational in the Chemicals task and concrete operations (2B) in the Pendulum task. 9.0 % (n=30) of the students were ranked at the concrete generalisation or formal operational level in the Pendulum task, but at the concrete operational level (2AB-2B) in the Chemicals task.

Table 8. The interconnection between the scores in the Pendulum and in the Chemicals tasks (Frequencies and percentage values of total).

		Chemicals task						
		2AB	2B	2B*	3A	3AB	3B*	Total
Pendulum task	2AB							
	2B	3 0.9%	3 0.9%	13 3.9%	10 3.0%	6 1.8%	1 0.3%	36 10.8%
	2B*	4 1.2%	8 2.4%	29 8.7%	37 11.1%	11 3.3%	1 0.3%	90 27.1%
	3A	1 0.3%	14 4.2%	33 9.9%	52 15.7%	45 13.6%	1 0.3%	146 44.0%
	3AB		3 0.9%	10 3.0%	24 7.2%	18 5.4%	1 0.3%	56 16.9%
	3B*				6 0.6%	2 0.6%		4 1.2%
	Total	8 2.4%	28 8.4%	85 25.6%	125 37.7%	82 24.7%	4 1.2%	332 100.0%

In this study there were no means to analyse the reliability of the Comparison task. Kallio (1998) has used a test-retest correlation as an indicator of reliability of the comparison task, which was .42. Demetriou and Efklides (1985) do not report any reliability data for their metacognitive task.

On the basis of these analyses the reliability of the Science Reasoning Tasks is at a sufficient level and the reliability level is in line with earlier research.

3.1.4 Interscorer agreement

In order to analyse the interscorer agreement and the validity of the scoring, two scorers (research assistant and the author) scored one randomly selected sample of the answers (answers of 30 students, 10 % of all). Correlations were used as an indicator of agreement. With the Pendulum task the correlation (the Kendall's tau-b) was .54 ($p<.001$), with the Chemicals .69 ($p<.001$) and with the Comparison task .47 ($p<.01$).

3.1.5 Validity of the tasks

SRT tasks are theoretically directly based on Inhelder and Piaget's (1958) theory concerning the development of formal reasoning. The Pendulum task primarily measures the schema of handling of variables involving the control and exclusion of variables. The Chemicals task also focuses on the schema of handling of variables (combinatorial thinking) as well as formal models, namely logical deduction from the given premises and constructing and using formal models.

Table 9. Descriptions of the skills measured in the Pendulum and Chemicals tasks (Shayer & Adey, 1981, see Kallio, 1998)

	Pendulum task	**Chemicals task**
2B*	Identifies the effect of the salient variable length, but cannot produce a valid reason to justify the deduction.	Can conceive all the combinations of four objects. Produces a qualitative model of two variables being sufficient for an effect.
3A	Can produce a plan for controlling all variables but one in testing for each possible effect (control of variables).	Produces an exhaustive set of combinations of 4 objects readily.
3AB	Can systematically exclude irrelevant variables in analysing experiments planned at level 3A, and thus can identify the non-effect of push even if this is counter-intuitive.	Can draw inferences from the combinations of the four chemicals used concerning what are necessary and sufficient conditions for an effect and its converse.
3B*	Can systematically resist the impulse to interpret experiments where more than one variable has been changed, and can integrate the two strategies of control and exclusion of variables.	Can produce a proof strategy to justify inferences made at the former level.

The theoretical background of the Comparison task is found in the neo-Piagetian model of development of metacognitive processes. The structure of the task was similar to the original version of the task used by Demetriou and Efklides (1985), but the content in this research was the Pendulum and the Chemicals tasks (see also Kallio 1998).

Table 10. Descriptions of metacognitive processes measured in the Comparison task (Kallio, 1998, based on Demetriou & Efklides, 1985)

	Comparison task - Metacognitive processes
1. No reflection	No indication of conscious reflection on the thought processes.
2. Reflection of the content of the task	Evaluation of manifest content of the task, i.e. the phenomenal features of the tasks are given in the evaluations.
3. Developing general analysis	Necessary operations for the solution of the tasks are described. Evaluation is, however, very general and holistic, and does not focus in detail on the specific parts of the operations or chains of operations used in them.
4. General analysis	The analysis has the same characteristic as at the third level, but the answers at this level are more extensive. Students are able to identify the process of keeping some variables constant while changing only one variable.
5. Developing specific analysis and integration	Differentiating and reducing thought operations and chains of reasoning to smaller components. The differences and similarities between the chains of logical reasoning used in both tasks are analysed in greater detail than in the former sub-stage. There is a tendency to combine the tasks with a single factor or factors found in both tasks.
6. Specific analysis and integration	The analysis has the same characteristics as at the third level, but the answers at this level are more extensive and include more specific descriptions of the thought processes.

3.1.6 Data analysis and presentation of results

The independent variables in the study were the sector of higher education (university/UAS), phase of studies (initial/intermediate/final), age, gender and prior education. The dependent variables were the stage of logical thinking i.e. causal reasoning ability (the Pendulum and the Chemicals tasks) and the level of metacognitive awareness of the reasoning process (the Comparison task) (Figure 4).

In the analysis of the effects of age as a contextual factor students were classified into the following three groups: 1) students at the age of 19-20, 2) students at the age of 21-23, and 3) students at the age of 24 and over.

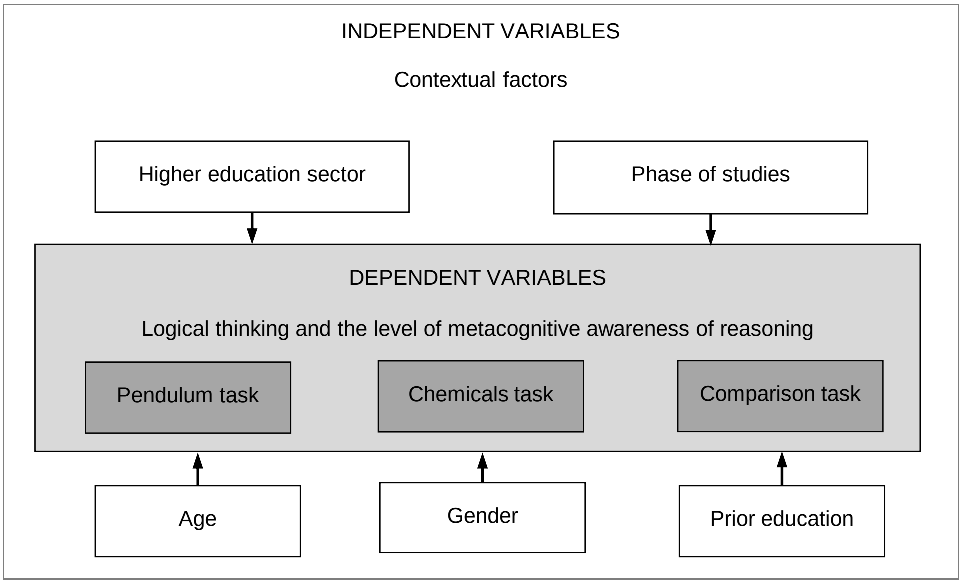

Figure 4. Dependent and independent variables in this study.

The statistical analysis of the data included the use of descriptive data and the One-way Anova procedures and General linear model analysis (SPSS programme).

The presentation of the results of the Pendulum task, the Chemicals task and the Comparison task is carried out in the following ways: the descriptive data and the results of the students in the different phases of studies in universities and in UASs are presented by using the symbols of the developmental stages, and the scores corresponding to the developmental stages are used when comparisons between the sectors and different student groups by phases are made (One-way Anova procedures). The analysis of the results was carried out in the same order in all the cases of the Pendulum, Chemicals and Comparison tasks. The process and the phases of the data analysis are described in Table 11.

Table 11. The focus of the interests and the methods used in data analysis.

Focus	Data analysis
The results of the logical thinking i.e. causal reasoning abilities and the level of metacognitive awareness of reasoning in the two higher education sectors	Descriptive analysis, crosstables
The differences between the sectors.	Independent samples t-test [1)]
The results of the logical thinking i.e. causal reasoning abilities and the level of metacognitive awareness of reasoning in the different phases of studies in the two higher education sectors.	Descriptive analysis, crosstables
The differences between the study phases within the sectors and between the sectors.	One-way Anova procedures, Post-hoc tests (Bonferroni) [1)]
The effect of the each contextual factor (age, gender, prior education, studies in qualitative and quantitative methodologies) on logical thinking i.e causal reasoning and metacognitive awareness of reasoning.	Independent samples t-test (the effects of gender), One-way Anova procedures (other contextual factors), Post-hoc tests (Bonferroni) [1)]
The interaction effects of the contextual factors, higher education sectors and study phases.	General liner model analysis/ Univariate analysis, Post-hoc tests (Bonferroni) [1)]

[1)] In cases when Levene's test indicated inhomogeneity of variances (when error variance of the dependent variable was not equal across groups) two methods were used: 1) the use of robust tests of equality of the means (Brown-Forsythe and Welch), and 2) normalisation of the independent variable. If the results of these two methods did not lead to different findings, the results of the original Anova procedures were used. If these methods resulted in different findings, the nonparametric tests of several independent samples (Kruskall Wallis H) were used in the analysis.

3.2 Study of the conceptions of scientific thinking and skill requirements in higher education studies

3.2.1 Descriptive characteristics of the subjects under study

The questionnaire concerning the epistemological beliefs of scientific thinking and students' conceptions about the skills and competencies needed in business studies in universities and UASs were sent to all students who participated in Science Reasoning Tasks. 155 students answered the questionnaire (30.9% of the UAS students and 65.3% of the university students). The following two tables (Table 12 and Table 13) present the descriptive data of these students.

Table 12. Higher education sector, phase of studies, age, gender study credits and years of studies of the students who answered both the science reasoning tasks and to the questionnaire.

* Information concerning the students' gender was available of 154 students

Higher education sector	Phase of studies	N	Age		Gender *		Study credits		Years of studies	
			M	SD	Female	Male	M	SD	M	SD
UAS	**Initial phase**	34	21.4	4.4	29	4	27.4	10.4	1.0	0.2
	Intermediate phase	8	24.1	2.6	4	4	76.8	13.0	2.4	0.8
	Final phase	17	32.1	7.6	17	0	134.1	7.6	3.4	0.9
	Total	59	24.6	6.9	50	8	64.8	48.4	1.9	1.2
University	**Initial phase**	33	22.9	5.9	18	15	32.2	12.8	1.1	0.3
	Intermediate phase	20	25.2	6.5	11	9	85.0	9.8	2.5	1.2
	Final phase	43	24.9	3.3	31	12	145.0	32.3	3.9	1.2
	Total	96	24.3	5.1	60	36	93.7	55.3	2.6	1.6
Total		155	24.4	5.8	110	44	82.7	54.5	2.4	1.5

Table 13. Prior education of the students who answered both the science reasoning tasks and the questionnaire.

Higher education sector	Phase of studies	N	Prior education: Matriculation examination	Upper secondary vocatational education	Matriculation examination + vocational education	Bachelor (UAS degree)	Bachelor/Master/ Licentiate (university degree)
UAS	**Initial phase**	34	29	2	2	1	0
	Intermediate phase	8	6	1	0	0	1
	Final phase	14	3	5	6	0	0
	Total	56	38	8	8	1	1
University	**Initial phase**	31	22	3	3	3	0
	Intermediate phase	19	13	1	3	2	0
	Final phase	38	25	0	2	6	5
	Total	88	60	4	8	11	5
Total		144	98	12	16	12	6

In order to assess the reliability of the results of the enquiry the data were compared to the data concerning the students who participated in scientific reasoning tasks (SRT data). The comparison of these two data showed some differences between the data in students' age, number of study credit and years of studies. Comparison of the means of students' age in these two data and independent samples t-test indicated that the average age of the students who answered both the enquiry and the scientific reasoning task was significantly higher than the average age of the students who answered only the scientific reasoning tasks ($t(485)= -2.183$, $p<.05$). The comparison of the means of the number of study credit in these two data and independent samples t-test revealed that the average number of study credits was significantly higher in the enquiry data ($t(491)= -2.193$, $p<.05$) and the mean of the number of study years was higher in the enquiry data ($t(491)= -2.186$, $p<.05$).

3.2.2 Questionnaire of students’ conceptions of scientific thinking and higher education studies

The aim was to find out students’ epistemological beliefs of scientific thinking and students’ conceptions of the skill requirements in university and UAS studies and the role of scientific thinking in their studies. The aim was also to explore the profiles of higher education studies in the two sectors by analysing and comparing the role of scientific thinking from the students’ perspective.

The questionnaire included five open-ended questions concerning students’ conceptions of scientific thinking, students’ conceptions of how scientific thinking develops during the studies, how scientific thinking abilities are supported by their studies and what kind of skills and competencies are needed in studies in universities and UASs. Also information on students’ prior education was requested.

3.2.3 Qualitative content analysis

Qualitative content analysis was applied to categorise the students’ answers to the questionnaire. The following publications were perused to provide background information when conducting the content analysis (Alasuutari, 2001; Cohen, Manion & Morrison, 2000; Creswell, 2005). I personally conducted the analysis of the answers given to the questionnaire. The analysis started by reading the answers several times and forming the first categorisations of the answers. The analysis focused on the manifest content of the students’ answers. In other words, analysis was based on the content aspect (what the text says) and aimed to describe the visible components (see, e.g., Graneheim & Lundman, 2004). The process of the content analysis progressed from detailed categorisation of the data to a more general level of categories. (See Appendix 9, for the descriptions of the content categories).

The content analysis of the responses to question 1. “What kind of skills and competencies do you need in your studies?” included 33 content categories in the first phase of analysis. After the data had been read several times, the categorisations were compressed to 6 content categories (including 3 sub categories). Question 3. “Do the studies in your university/UAS promote the development of scientific thinking?” and “If yes, how is scientific thinking promoted?” included 21 categories in the first phase of analysis, which were finally grouped into 7 categories.

The content analysis of the answers to question 2. “What is scientific thinking?” included 49 very detailed and exact groupings of the content in the first phase of the categorisation (see the Appendix 9 for the contents of the detailed categories). After that, detailed categorisations were compressed and grouped into ten larger categories, which were also entitled along with the content. At this phase a fellow-researcher also tested the firmness of the categorisation by reading and classifying a part of the students' answers. The categorisation was once more modified after the negotiations and the final categorisation comprised 8 categories (including 4 subcategories). In addition, the categories were also divided into two groups according to the breadth and comprehensiveness of the expressions in the categories (surface and deeper level expressions). To test the reliability of the analysis one-fifth of the pre-marked answers (31 answers) were analysed and classified by a fellow researcher. The classification exceeded 90.1% agreement. The agreement of the suitable category was negotiated when a disagreement in classification occurred. See Figure 5 for the phases of the content analysis concerning the conceptions of scientific thinking.

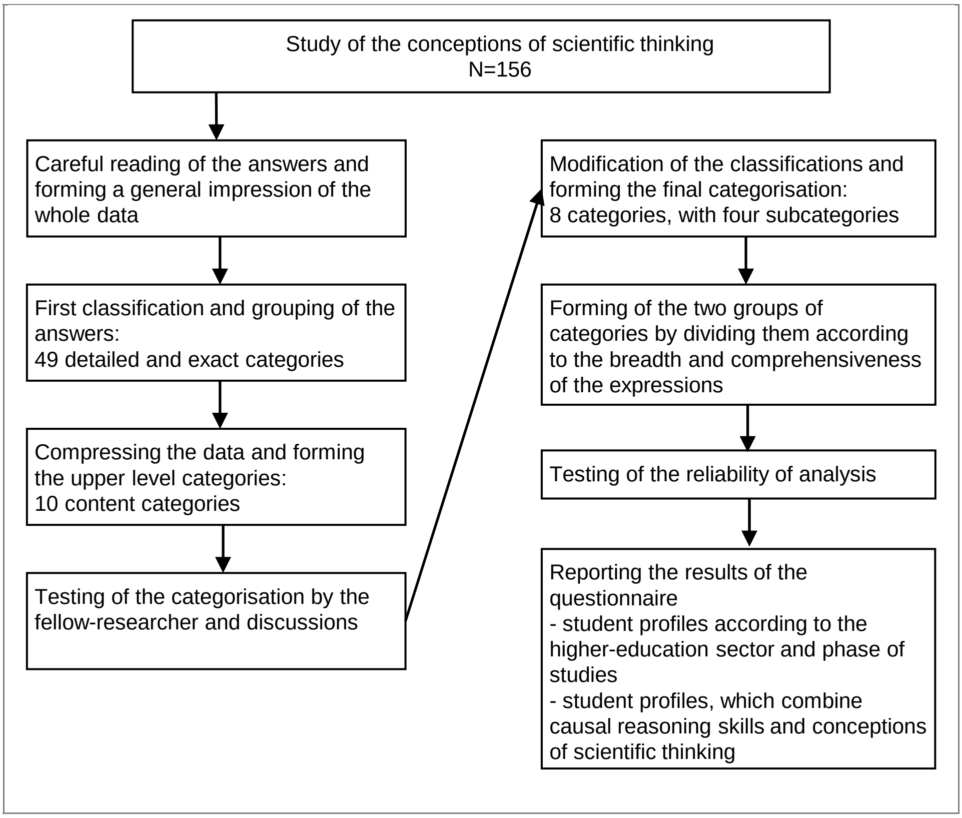

Figure 5. The phases of the content analysis concerning students' conceptions of scientific thinking.

4 RESULTS

4.1 Logical thinking skills

This chapter presents the results of students' logical thinking skills (research questions 1, 1.1, 1.2, 1.3). The measured developmental stages of logical thinking were the following:

Table 14. Developmental stages of logical thinking.

Pendulum and Chemicals tasks

Developmental stage	Symbol	Score
Early concrete reasoning	2A	1
Mid concrete reasoning	2AB	2
Full concrete operational	2B	3
Concrete generalisation	2B*	4
Early formal operational	3A	5
Full formal operational	3AB	6
Formal generalisation	3B*	7

The results of the Pendulum and Chemicals tasks are both used in this study to indicate the students' developmental stages of logical thinking at the stage of formal operations. However, because of the slightly different emphasis and foci of these tasks they are analysed as parallel indicators of students' reasoning skills, and are not combined into one measure (see Chapter 4.2 Research method). The Pendulum task primarily measures the schema handling of variables (control and exclusion of variables), whereas the Chemicals task also focuses on formal models (logical deduction from the given premises and constructing and using formal models).

In the case of both measures of logical thinking, Pendulum and Chemicals, and in the case of Comparison task measuring metacognitive awareness, the results are presented in the same order:

1) reporting the developmental stages of reasoning skills and metacognitive awareness of the students in universities and in UASs and also differences between the sectors (research questions 1.1 and 1.1.1. as well as 1.2 and 1.2.1),

2) reporting the developmental stages and analysing differences between the initial, intermediate and final phases of studies in universities and UASs (research questions 1.1.2. and 1.2.2), and

3) analysing the effects of other contextual factors (gender, age and prior education) (research questions 1.1.3 and 1.2.3).

4.1.1 Results of the Pendulum task

Students in universities and UASs

Distribution of the scores in the Pendulum task indicated that 77.5% of university students have reached the stage of formal operations (3A-3B*), which can be seen as a precondition for logical thinking (see Table 15). In the UAS sector the percentage value of the students at that stage was 50.3 whereas in the university sector the score distribution in the Pendulum task was balanced more at the higher levels of formal reasoning, the balance in the UAS sector was more at the lower levels of reasoning. Almost one half of the UAS students were placed at the concrete operational levels (2B-2B*), which presumes that students in the context of the pendulum type of experimental setting identifies the effect of the salient variable, but cannot produce a valid reason to justify the deduction.

Table 15. Frequencies and percentage values of university and UAS students at each developmental sub-stage in the Pendulum task.

Developmental stage	Pendulum task			
	University students		UAS students	
	f	%	f	%
2B	10	6.8	26	13.9
2B*	23	15.6	67	35.8
3A	76	51.7	72	38.5
3AB	34	23.1	22	11.8
3B*	4	2.7	0	0
Total	147	100	187	100

The biggest single group of students at both sectors was placed at the development stage 3A, which was reached by 51.7% of university students and 38.5% of UAS students. In the context of the Pendulum task stage 3A presumes that the student can produce a plan for controlling all variables but one in testing for each possible effect. Students who showed even higher formal reasoning abilities in the Pendulum task were able to systematically exclude irrelevant variables in analysing experiments for controlling the variables, identify the non-effects of the variables and also (at the level 3B*), interpret experiments where more than one variable has been changed, and integrate the two strategies of control and exclusion of variables. The highest stage of formal reasoning (3B*) was reached by only four students and they all represented the university sector.

The comparison of the means of the scores (independent samples t-test) reveals that the reasoning skills among the university students were on a higher level than the skills among the UAS students. On average, the scores of both university students and UAS students were at the stages of concrete generalisation (2B*) and early formal operational (3A) (see Table 16).

Table 16. Means of scores in the Pendulum task in the university sector and UAS sector, standard deviations and significance testing of the means of scores.

	Universities			UASs			Both sectors			t
	N	Mean	SD	N	Mean	SD	N	Mean	SD	
Pendulum task	147	4.99	0.88	187	4.48	0.88	334	4.71	0.91	**t(332)= -5.292, p < .004**

Results at the different study phases

The Pendulum task indicates that nearly 80% of the university students at each study phase can be classified as formal operational (3A-3B*) (see the Table 17). At the highest stages, i.e. full formal operational (3AB) and formal generalisation (3B*), one fifth of the students were at the initial phase, under ten percent of the students were at the intermediate phase and one third of the students at the final phase of university studies. Two students both at the initial and at the final phase reached the stage of formal generalisation (3B*).

In the UAS sector approximately one half of the students at each study phase reached the formal operational stage (3A-3B*). The other half of the students were ranked at the stage of concrete operations (2B-2B*). Full formal operations (3AB) were shown by nearly one-fifth of the students at the initial phase and at the intermediate phase and only by a few percent of the final phase students.

Table 17. The frequencies of students (and percentage values within phase of studies) at each developmental stage of the Pendulum task.

Pendulum task														
Study phase	**University students**						**UAS students**							
	Initial		Inter-mediate		Final		Initial		Inter-mediate		Final		Total	
Develop-mental stage	f	%	f	%	f	%	f	%	f	%	f	%	f	%
2B	4	7.7	3	9.4	3	4.8	15	12.7	4	14.8	7	16.7	36	10.8
2B*	9	17.3	4	12.5	10	15.9	44	37.3	9	33.3	14	33.3	90	26.9
3A	28	53.8	17	53.1	31	49.2	43	36.4	9	33.3	20	47.6	148	44.3
3AB	9	17.3	8	25.0	17	27.0	16	13.6	5	18.5	1	2.4	56	16.8
3B*	2	3.8	0	0.0	2	3.2	0	0.0	0	0.0	0	0.0	4	1.2
Total	52	100	32	100	63	100	118	100	27	100	42	100	334	100

The Pendulum task did not indicate any significant differences between the study phases within the sectors. However, some differences were found between the phases of the two sectors ($F(5.328)=6.012$, $p <.001$, $\eta = .084$): the post hoc tests (Bonferroni) of the one-way ANOVA procedure showed that at the final phase of studies the university students scored better than the UAS students at the same phase of studies ($p < .01$). At the initial and intermediate phases of studies there were no significant differences. See Table 18 for the means and standard deviations of the different study groups.

Table 18. Group means and standard deviations in the Pendulum task for the university and UAS students at the initial, intermediate and final phases.

	Pendulum task					
	University students			**UAS students**		
	N	Mean	SD	N	Mean	SD
Initial phase	52	4.92	0.90	118	4.51	0.88
Intermediate phase	32	4.94	0.88	27	4.56	0.97
Final phase	63	5.08	0.88	42	4.36	0.79
Total	147	4.99	0.88	187	4.48	0.88

Effects of the individual factors on the results of the Pendulum task

Age and gender

Neither the student's age nor gender had significant effects on the results of the Pendulum task. General linear model/univariate analysis did not result in any interaction effect either between the sectors and age or between the sectors and gender.

Prior education[10]

The pendulum task indicated a significant effect of prior education on the causal reasoning abilities, and the differences between the prior education groups were significant ($F(5,328)= 3.023$, $p< .05$, $\eta = .044$). Bonferroni's post hoc test with its significant difference procedure ($\alpha =.05$) indicated that the students with vocational education as prior education scored the lowest and there were significant differences between that student group and students who had the matriculation examination or the UAS Bachelor's degree as a prior education. Means and standard deviations for each prior education group are presented in Table 19 and the differences between the groups are presented in Table 20.

[10] The data concerning the students' prior education did not cover the whole sample. Students without the prior education data (n=64) were categorised as a separate group to make it possible to evaluate if their results in the tasks differentiated significantly from the results of the other students.

Table 19. Group means and standard deviations for the different study groups in the Pendulum task.

	Pendulum task								
	University students			**UAS students**			**Total**		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Vocational education	5	4.20	0.84	12	4.00	0.85	17	4.06	0.83
Matriculation examination	84	5.05	0.87	129	4.54	0.86	213	4.74	0.88
Matriculation examination + vocational education	8	4.88	1.27	11	4.45	0.82	19	4.63	1.01
Bachelor's (UAS degree)	13	5.08	0.64	3	5.00	1.00	16	5.06	0.68
Bachelor's/Master's/ Licentiate (university degree)[11]	5	5.40	0.55				5	5.40	0.55
No information on the prior education	32	4.91	0.10	32	4.38	0.94	64	4.64	1.00
Total	147	5.00	0.88	187	4.48	0.88	334	4.71	0.91

Table 20. Prior education groups having significant differences in the results of Pendulum task.

Pendulum task				
Prior education group with higher scores	**Prior education group with lower scores**	**Mean difference**	**Std. Error**	**α**
Matriculation examination	Vocational education	.68	.23	α <.05
UAS Bachelor's degree	Vocational education	1.00	.31	α <.05

The interaction effect between the higher education sector and prior education was also significant in the results of the Pendulum task ($F(10.323) = 4.019$, $p<.001$, $\eta = .111$). Bonferroni's post hoc test with its significant difference procedure ($\alpha = .05$) showed differences between some of the prior education groups in the Pendulum and Chemicals tasks. In the case of the Pendulum task university students with the matriculation examination as a prior education reached significantly higher scores than UAS students with the matriculation examination or vocational education. The results of students without the prior education data differentiated from the other prior education groups only in one case (in the results of the Pendulum task the prior education group differentiated from the university students with the matriculation examination as a prior education). The results are presented in Table 21.

[11] Among the UAS students there was one student who had a university Bachelor's degree as a prior education. In this analysis she is classified in the prior education group of UAS Bachelor's.

Table 21. Significant differences between the prior education groups in the two higher education sectors in the results of Pendulum tasks.

Pendulum task				
Prior education group with higher scores	**Prior education group with lower scores**	**Mean difference**	**Std. Error**	**α**
University / Matriculation examination	UAS / Matriculation examination	.51	.12	α <.01
University / Matriculation examination	UAS / Vocational education	1.05	.27	α <.01

4.1.2 Results of the Chemicals task

Students in universities and UASs

In the Chemicals task approximately 60% of the students in both sectors showed the stage of formal reasoning (3A-3B*) (see Table 22). In the case of the UAS students the scores were higher than in the Pendulum task. Furthermore, the most mature forms of formal reasoning (3AB & 3B*) were more common in the Chemicals task than in the Pendulum task in both sectors: these abilities were shown by 31.3% of university students and 21.1% of UAS students. Four UAS students, but none of the university students (contrary to the Pendulum task results) reached the highest sublevel of causal reasoning (3B*). These levels presume that students can draw inferences from the combinations of different variables and analyse what are necessary and sufficient conditions for an effect and its converse, and also produce (at the highest sub-stage) a proof strategy to justify inferences made at the former stages. On the grounds of these results it can be stated that these students had good abilities not only in the schema of control and exclusion of variables, but also in logical deduction and constructing and using formal models.

As in the case of the Pendulum task the biggest single group of students in this Chemicals case was placed at the substage of 3A, which means in the context of the Chemicals task that students can produce a qualitative model of the variables affecting the output and produce an exhaustive set of combinations of all possible (in this case 4) objects.

A difference between the results of the Pendulum and Chemical tasks was that in the case of the Chemicals task there were many students not only in the UAS sector, but also in the university sector, who could reach only the stages of concrete operations (2AB-2B*): the percentages representing these levels were 33.3% in the university sector and 39.7%. in the UAS sector At these concrete operational stages students are able to conceive all possible effecting variables of the experimental setting, but cannot produce an exhaustive set and model of all the combinations of variables affecting the output. These developmental stages of cognitive operations are not sufficient for logical and scientific thinking.

Table 22. Frequencies and percentage values of university and UAS students at each developmental substage in the Chemical tasks.

Developmental stage	Chemicals task			
	University students		UAS students	
	f	%	f	%
2AB	3	2.0	5	2.6
2B	10	6.8	18	9.5
2B*	36	24.5	50	26.5
3A	52	35.4	76	40.2
3AB	46	31.3	36	19.0
3B*	0	0	4	2.1
Total	147	100	189	100

The comparison of the mean scores of the two sectors (independent samples t-test) did not indicate any significant differences. As in the case of the Pendulum task, the mean scores of the Chemicals task indicated that formal reasoning abilities in both university students and UAS students were on average at the stages of concrete generalisation (2B*) and early formal operational (3A) (means of scores varied between 4.87 - 4.70).

Results at the different study phases

The frequencies and percentages within the study phase at the developmental sub-stages in the Chemicals task are shown in Table 23. In the university sector nearly one half of the initial and intermediate phase students and over 80% of the final phase students showed the formal operational stage of thinking (3A-3B*) in the Chemicals task. Among the UAS students the results also indicated that over one half of the students reached the stage of formal operations (3A-3B*). However, in the final phase only 40% reached that stage and almost 60% of the students can be classified as at the stage of concrete operations.

Table 23. Frequencies of students (and percentage values within each phase of study) at each developmental stage on the Chemicals task.

Chemicals task														
Study phase	**University students**						**UAS students**							
	Initial		Interme-diate		Final		Initial		Interme-diate		Final		Total	
Develop-mental stage	f	%	f	%	f	%	f	%	f	%	f	%	f	%
2AB	1	1.9	2	6.3	0	0	2	1.7	2	7.1	1	2.4	8	2.4
2B	6	11.5	2	6.3	2	3.2	10	8.3	1	3.6	7	17.1	28	8.3
2B*	16	30.8	10	31.3	10	15.9	25	20.8	9	32.1	16	39.0	86	25.5
3A	16	30.8	8	25.0	28	44.4	56	46.7	6	21.4	14	34.1	128	38.1
3AB	13	25.0	10	31.3	23	36.5	26	21.7	7	25.0	3	7.1	82	24.3
3B*	0	0.0	0	0	0	0	1	0.8	3	10.7	0	0	4	1.2
Total	52	100	32	100	63	100	120	100	28	100	41	100	336	100

The Pendulum task indicated differences between sectors, but not between the study phases within the sectors. Instead, in the case of the Chemicals task one-way ANOVA analysis brought out some differences both within and between the sectors ($F(5.330)=4.071$, $p < .01$, $\eta = .058$). Bonferroni's post hoc test with its significance procedure showed that within the UAS sector the scores of final phase students were significantly lower than the scores at the initial phase ($\alpha < .05$). Within the university sector the scores developed higher along the study phases, but the difference was not significant between the phases. When comparing the results of study phases between the sectors, it can be noticed that at the initial and intermediate phases there were no significant differences between the sectors, but at the final phase of studies university students scored significantly higher ($\alpha < .001$). See Table 24 for the means and standard deviations of the different study groups.

Table 24. Group means and standard deviations in the Chemicals task for the university and UAS students in the initial, intermediate and final phases.

	Chemicals task					
	University students			**UAS students**		
	N	Mean	SD	N	Mean	SD
Initial phase	52	4.65	1.05	120	4.81	0.96
Intermediate phase	32	4.69	1.18	28	4.86	1.35
Final phase	63	5.14	0.80	41	4.27	0.92
Total	147	4.87	1.00	189	4.70	1.04

Effects of the individual factors on the results of Chemicals task

Age and gender

As with the Pendulum task, the Chemicals task did not indicate any significant effects of the student's age on causal reasoning abilities. However, univariate analysis of variance indicated an interaction effect of the sector and age ($F(2.326)=4.010$, $p < .05$, $\eta=.024$) in the case of the Chemicals task. In the university sector the scores rose in accordance with the student's age, while in the UAS sector the trend was the opposite: the scores were highest among the youngest students and lowest among older students. See Table 25 for the means and standard deviations of the age groups in both sectors.

Table 25. Means and standard deviations of the Chemicals task scores for the different age groups in both sectors.

	Chemicals task					
	University students			**UAS students**		
	N	Mean	SD	N	Mean	SD
Age 19-20	28	4.68	0.19	69	4.97	0.12
Age 21-23	63	4.84	0.13	74	4.61	0.12
Age 24 ->	56	5.00	0.14	42	4.43	0.16
Total	147	4.99	0.88	183	4.49	0.88

Gender did not have a significant effect on the results of the Chemicals tasks, nor did the univariate analysis of variance indicate any interaction between the sector and gender.

Prior education[12]

As in the case of the Pendulum task, the Chemicals task also indicated that the prior education had a significant effect on causal reasoning abilities: differences between the prior education groups were significant ($F(5.330)= 2.786$, $p< .05$, $\eta = .041$). Bonferroni's post hoc test with its significant difference procedure ($\alpha= .05$) indicated that students with vocational education as a prior education scored lowest in both tasks and there were significant differences between that student group and students with the matriculation examination or the UAS Bachelor's degree as a prior education. Means and standard deviations for each prior education group are presented in Table 26 and the differences between the groups are presented in Table 27.

[12] The data concerning the students' prior education did not cover the whole sample. Students without the prior education data (n=64) were categorised as a separate group to make it possible to evaluate if their results on the tasks differentiated significantly from the results of the other students.

Table 26. Group means and standard deviations for the different study groups in the Chemicals task.

	Chemicals task								
	University students			**UAS students**			**Total**		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Vocational education	5	3.20	1.10	13	4.46	1.13	19	4.16	1.21
Matriculation examination	84	4.89	0.93	128	4.79	1.04	212	4.83	1.00
Matriculation examination + vocational education	8	5.25	0.71	12	4.42	0.90	20	4.75	0.91
Bachelor's (UAS degree)	13	5.31	0.86	3	5.33	1.16	16	5.31	0.88
Bachelor's/Master's/ Licentiate (university degree)[13]	6	5.00	1.10	0	0.0	0.0	5	5.00	1.23
No information on the prior education	32	4.78	1.04	32	4.47	1.02	64	4.63	1.03
Total	148	4.87	1.00	188	4.70	1.04	336	4.77	1.02

Table 27. Prior education groups, which had a significant difference in the results of Chemicals tasks.

Chemicals task				
Prior education group with higher scores	**Prior education group with lower scores**	**Mean difference**	**Std. Error**	**α**
UAS / Bachelor's degree	Vocational education	1.15	.34	α <.05

Univariate analysis of variance also indicated a significant interaction effect between the higher education sector and prior education also in the results of the Chemicals task ($F(10.325) = 2.588$, $p<.01$, $\eta = .074$). Bonferroni's post hoc test with its significant difference procedure ($\alpha=.05$) showed differences between some of the prior education groups. In the case of the Chemicals task the university students with vocational prior education had significantly lower scores than most of the other university students and also lower scores than the UAS students who had taken the matriculation examination. The results are presented in Table 28.

[13] Among the students from the university of applied sciences there was one student who had a university Bachelor's degree as a prior education. In this analysis she is classified in the prior education group of UAS Bachelor's.

Table 28. Significant differences between the prior education groups at the two higher education sectors in the results of the Chemicals task.

Chemicals task				
Prior education group with higher scores	**Prior education group with lower scores**	**Mean difference**	**Std. Error**	**α**
University/ Matriculation examination	University / Vocational education	1.69	.46	α <.05
UAS/ Matriculation examination	University / Vocational education	1.59	.46	α <.05
University / Matriculation examination + vocational education	University / Vocational education	2.05	.57	α <.05
University / UAS Bachelor's degree	University / Vocational education	2.11	.53	α <.01

4.1.3 Summary of the results of logical thinking skills

The results and analysis described above in this chapter indicate that there are some factors which have an effect on the logical thinking skills of the higher education students. These factors include the higher education sector, prior education and the student's age (the Figure 8.). The Pendulum task indicated that students in the university sector have more advanced reasoning abilities than the UAS students. When study phases were compared, it appeared that in the results of the two reasoning tasks the university students at the final phase of their studies had better reasoning abilities than the UAS students at the same phase of studies. The Chemicals task indicated that the UAS students at the final phase had weaker reasoning abilities than the students in the initial and intermediate phases. Also, different age groups in the two sectors had different results in the Chemicals task: in the university sector the scores were higher in accordance with the student's age, while in the other sector the scores were highest among the youngest students and lowest among older students. Prior education had an effect on the results in several ways. The Pendulum task indicated that even if both groups of students had the matriculation examination as a prior education, students in the university sector had better reasoning abilities. The results of both tasks showed that vocational education as a prior education seems to indicate weaker reasoning abilities than the matriculation examination or the Bachelor's degree as a prior education. Especially in the university sector vocational education as a prior education was typical for students who showed poor success in reasoning tasks.

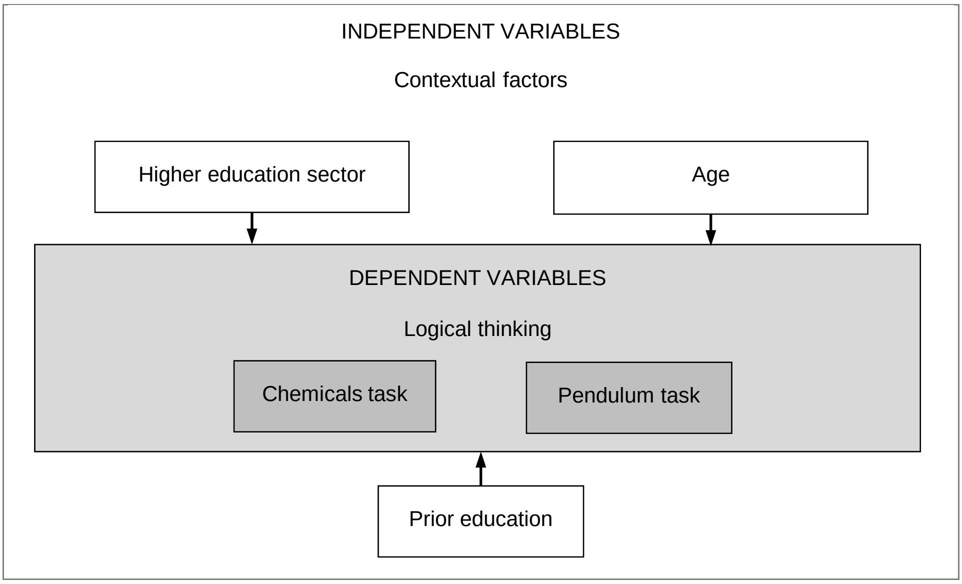

Figure 6. Contextual factors affecting higher education students' logical thinking skills.

4.2 Metacognitive awareness of logical thinking processes

This Chapter presents the results of the Comparison task, which measured students' metacognitive awareness of reasoning process (research questions 1, 1.1, 1.2, 1.3). The measured levels of reflection and analysis of the logical reasoning process are described in the Table 29.

Table 29. Developmental ranges of the task and descriptions of the levels.

Comparison task		
Levels	**Description of the level**	**Score**
No reflection	No indication of conscious reflection on the thought processes	1
Reflection of the content of the task	Evaluation of manifest content of the task	2
Developing general analysis	Necessary operations for the solution of the tasks are described. Evaluation is, however, very general and holistic.	3
General analysis	The analysis has the same characteristics as the third level, but the answers are more extensive.	4
Developing specific analysis and integration	Differentiating and reducing thought operations and chains of reasoning to smaller components.	5
Specific analysis and integration	The answers at this level are extensive and include more specific descriptions of the thought processes.	6

Lowest levels of metacognitive development, 1-2
Intermediate levels representing a general analysis level of metacognitive awareness, 3-4
Highest levels of metacognitive awareness, 5-6

Metacognitive awareness of the reasoning processes among students in universities and UASs

Table 30 shows the frequencies and percentage values for university and UAS students at each developmental level in the Comparison task. The results showed that 56.2% of the UAS students and 42.5% of the university students were at the two lowest levels of metacognitive skills: at the level of no reflection (level 1) and at the level of reflection of the content of the task (level 2). The following presents two examples of students' answers at this level:

> *The Pendulum tasks were boring and difficult to understand (however it was early morning and my brain was not yet functioning).The Chemicals tasks were much nicer and I didn't have to think about the answers as much. The answers to the Chemicals tasks were easily visible once you knew the "tactics".* (Level 1, UAS student at the initial phase, 61)

> *I thought about the Pendulum task by sketching it in my head, wereas with the Chemicals tasks I did not have to think so much about what the liquids looked like. There was more mathematical thinking involved when I thought of the mixes of different compounds. It is possible that I started to solve the Pendulum task more based on feelings than facts.* (Level 2, University student at the initial phase of studies, 27)

The levels of developing general analysis (level 3) and general analysis (level 4) categorised 43.8% of UAS students and 55.6% of the university students. Characteristic for this intermediate level of metacognitive abilities (including levels 3 and 4) is the ability to describe the necessary operations needed for the solution of the tasks. Evaluation at this level is still very general and holistic, and does not focus in detail on the specific parts of the operations or the chains of operations used in them. The following are examples of students' answers at levels 3 and 4:

> *I thought the tasks were similar since both of them involved studying the effects of various combinations to the end result. In both tests one aims to identify the important factors, i.e. the ones that affect the end result, as well as the factors that have little or no impact on the end result by changing the components of the test. Both tests progressed in a similar manner, that is by expanding, and I noticed that my own solution or thinking changed. In both tasks the problem solving took place bit by bit.* (Level 3, UAS student at the final phase, 94p)

> *The tasks were in some sense similar in that in both one needed to figure out cause-and-effect relationships between the small factors and the end result. In both tasks one had to be able to take into account all factors which possibly had an impact on the end result and compare these factors to figure out their significance. In addition the task description first involved the formulation of some kind of hypothesis to help solve the task. It was essential in the tasks that only one factor was changed at any*

given time as otherwise one could not be sure of the interrelationship of the factors. (Level 4, University student at the initial phase of studies, 22)

Three university students (2.1%) achieved the level of developing specific analysis and integration (level 5), but no one reached the highest level (level 6, specific analysis and integration). These highest levels of metacognitive awareness were not achieved by any UAS student. The key indicators at level 5, developing specific analysis and integration, is that students are able to differentiate and reduce thought operations and chains of reasoning to smaller components. The differences and similarities between the chains of logical reasoning used in both tasks are analysed in greater detail than in the former sub-stage. There is also a tendency to combine the tasks with a single factor or factors found in both tasks. The following answer was scored at level 5:

I thought about what affects what and whether some result is a combination of things. Or can a given factor be excluded from analysis, as it has no significance for the end result. In the Pendulum task I tried to think about the answers so that only one of the three variables was different. And then compare how this different variable affected the result. In the Chemicals task you also had to compare the impact of substances on one another. And based on the results I excluded different combinations which did not have an effect. (Level 5, University student at the initial phase (131)

Table 30. Frequencies and percentage values for university students and UAS students at each developmental level in the Comparison task.

Comparison task						
Level of metacognitive awareness	**University students**		**UAS students**		**Total**	
	f	%	f	%	f	%
1 Level of no reflection	9	6.3	16	9.0	25	7.8
2 Level of refection of the content of the task	52	36.1	84	47.2	136	42.2
3 Level of developing general analysis	62	43.1	71	39.9	133	41.3
4 Level of general analysis	18	12.5	7	3.9	25	7.8
5 Level of developing specific analysis and integration	3	2.1	-		3	0.9
6 Level of specific analysis and integration	-		-		-	
Total	144	100	178	100	322	100

The independent samples t-test indicated that the difference between the sectors was significant ($t(320)= -3.378$, $p <.01$) (see Table 31.). The means of the Comparison task scores show that, in general, the university sector students are able to identify and describe the reasoning operations that they have performed while solving the tasks (general analysis of the reasoning process). Evaluation is, however, very general and holistic, and not focused in detail on the specific parts of the operations or chains of operations. In the UAS sector the mean of the scores was at the lower level of metacognitive awareness, i.e. the level of reflection, which focuses only on the content of the task.

Table 31. The means and standard deviations of the Comparison task scores in the university and UAS sectors, and significance testing of difference between the scores.

	Universities			UAS			Both sectors			
	N	Mean	SD	N	Mean	SD	N	Mean	SD	**t**
Comparison task	144	2.68	0.850	178	2.39	0.706	322	2.52	0.786	**t(320)= -3.378, p =.001**

Metacognitive awareness of the reasoning processes at different phases of studies

The frequencies and percentage values within the phase of studies at each developmental level in the Comparison task are given in Table 32. The Comparison task indicates that in the UAS sector approximately one half of students at each phase can be categorised in the lowest levels of metacognitive awareness (levels 1-2). The abilities of the other half of the students are at the intermediate levels (levels 3-4) of metacognitive abilities.

In the university sector approximately one half of the initial phase students, over 70% of the intermediate phase students and approximately one fifth of the final phase students demonstrated the lowest levels of metacognitive skills (levels 1-2). The intermediate levels of metacognitive awareness (3-4) were achieved by one half of the initial phase students, 30% of the intermediate phase students and a little over 70% of the final phase students. One student at the initial phase of university studies and two students at the final phase of studies achieved the highest levels of metacognitive awareness (level 5 – developing specific analysis and integration).

Table 32. Frequencies and percentage values within the phase of studies at each developmental level in the Comparison task.

Phase of studies	UAS students						University students							
	Initial phase		Intermedi-ate phase		Final phase		Initial phase		Intermedi-ate phase		Final phase		Total	
Level	f	%	f	%	f	%	f	%	f	%	f	%	f	%
1	10	8.8	2	8.7	4	9.8	4	8.0	4	12.5	1	1.6	25	7.8
2	58	50.9	9	39.1	17	41.5	20	40.0	19	59.4	13	21.0	136	42.2
3	43	37.7	10	43.5	18	43.9	22	44.0	9	28.1	31	50.0	133	41.3
4	3	2.6	2	8.7	2	4.9	3	6.0	-	-	15	24.2	25	7.8
5	-	-	-	-	-	-	1	2.0	-	-	2	3.2	3	0.9
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	144	100	23	100	41	100	50	100	32	100	62	100	322	100

In the UAS sector the differences between the phases were not significant. In the university sector the achievement of the final phase student group was significantly better than the results of the initial ($\alpha<.01$) and intermediate phase students ($\alpha<.001$). ANOVA procedure also indicated differences between the study phases of the two sectors ($F(5,316)=9.794$, $p< .001$, $\eta = .134$). Bonferroni's post hoc test with its significant difference procedure ($\alpha=.05$) indicated that the group mean of the university students at the final phase was significantly ($\alpha<.001$) better than the group mean of UAS students at the final phase. Final phase university students were also significantly better than the UAS students at the initial ($\alpha<.001$) and intermediate phases ($\alpha< .05$). The group means and standard deviations for the study groups are shown in the Table 33.

Table 33. The means and standard deviations in the Comparison task for the university students and UAS students in the initial, intermediate and final phase of studies.

	Comparison task					
	University students			UAS students		
	N	Mean	SD	N	Mean	SD
Initial phase	50	2.54	0.81	114	2.34	0.68
Intermediate phase	32	2.16	0.63	23	2.52	0.79
Final phase	62	3.06	0.81	41	2.44	0.74
Total	144	2.68	0.85	178	2.39	0.71

Effects of the contextual factors on metacognitive awareness of the reasoning processes

The effects of three contextual factors on metacognitive abilities were analysed: the effects of age, gender and prior education. The effects of each contextual factor is analysed first separately using the one-way ANOVA procedure (independent samples t-test was used in analysing the effect of gender) and then the possible interactions between the higher education sector and the contextual factor are analysed using the general linear model/ univariate analysis of variance.

The data concerning the students' prior education and the studies in methodologies did not cover the whole sample. Students without the prior education data (n=64) and students without the data of studies in methodologies (n= 173) were categorised as separate groups to make it possible to evaluate if their results on the tasks differed significantly from the results of the other students.

Age

One-way ANOVA showed that the different age groups of students differed from each other in the results of the comparison task ($F\ (2.315) = 3.052$, $p < .05$, $\eta = .019$). Bonferroni's post hoc test with its significant difference procedure (α=.05) indicated that the student group at the age of 24 and over scored better than the student group at the age of 21-23 (α=.054). Multivariable analysis of variance did not indicate any interaction effect between the higher education sector and age in the results of the Comparison task.

Table 34. Means and standard deviation of the comparison task results for the three age groups.

Age	**Comparison task**		
	N	Mean	SD
19-20	95	2.47	0.71
21-23	126	2.43	0.75
24 ->	97	2.68	0.88
Total	318	2.52	0.80

Gender

Gender did not have a significant effect on the results of the Comparison task. Nor was any interaction found between the sector and gender in the results of this task.

Prior education[14]

The nonparametric tests of several independent samples (Kruskall Wallis H) were used in the analysis of the differences of the Comparison task scores between the six prior education groups. The scores differed from each other significantly (χ^2 =3.825, p=.050). Students with vocational education as a prior education had the lowest scores (M=2.17) and students with the UAS Bachelor's degree (M=3.06) and students with the University Bachelor's/Master's/ Licentiate degree (M=3.00) scored highest. When the prior education groups were defined for both higher education sectors separately (six groups in both sectors) no significant differences between the groups were found in the results of the Comparison task (χ^2 =2.716, p=.099). See Table 35 for the means and standard deviations of the Comparison task scores of each prior education groups.

Table 35. Group means and standard deviations of the Comparison task scores of each prior education group.

	Comparison task		
	N	Mean	SD
Vocational education	18	2.17	0.62
Matriculation examination	199	2.51	0.71
Matriculation examination + vocational education	20	2.40	0.75
Bachelor's (UAS degree)	16	3.06	1.06
Bachelor's/Master's/ Licentiate (University degree)[15]	5	3.00	1.00
No information on the prior education	64	2.50	0.91
Total	322	2.52	0.78

4.2.1 Summary of the results of metacognitive awareness

Based on the analysis described above in this chapter it seems that mainly the same factors which had an effect on the higher education students' reasoning skills also have an effect on the students' metacognitive awareness abilities. These factors are the higher education sector, age and prior education (see Figure 9). As in the reasoning tasks, also in the Comparison task students in the university sector reached higher results. Also the student's age played a role in

[14] The data concerning the students' prior education did not cover the whole sample. Students without the prior education data (n=64) were categorised as a separate group to make it possible to evaluate if their results on the tasks differed significantly from the results of the other students.

[15] Among the UAS students there was one student, who had a university Bachelor's degree as a prior education. In this analysis she is classified in the prior education group of UAS Bachelors.

the Comparison task results: students at the age of 24 and over had better metacognitive abilities than the other students. Prior education divided the student group in the following way: students with the Bachelor's or Master's degree achieved higher results than the students with other prior education. The higher the prior education the students had, the better they scored in this comparison task, which measured the reflective skills of analysing the reasoning processes. Contrary to the results of causal reasoning skills the comparison task also indicated that the phase of studies had an influence on the results: university students in the final phase of studies had better metacognitive abilities than all other student groups from the universities and UASs.

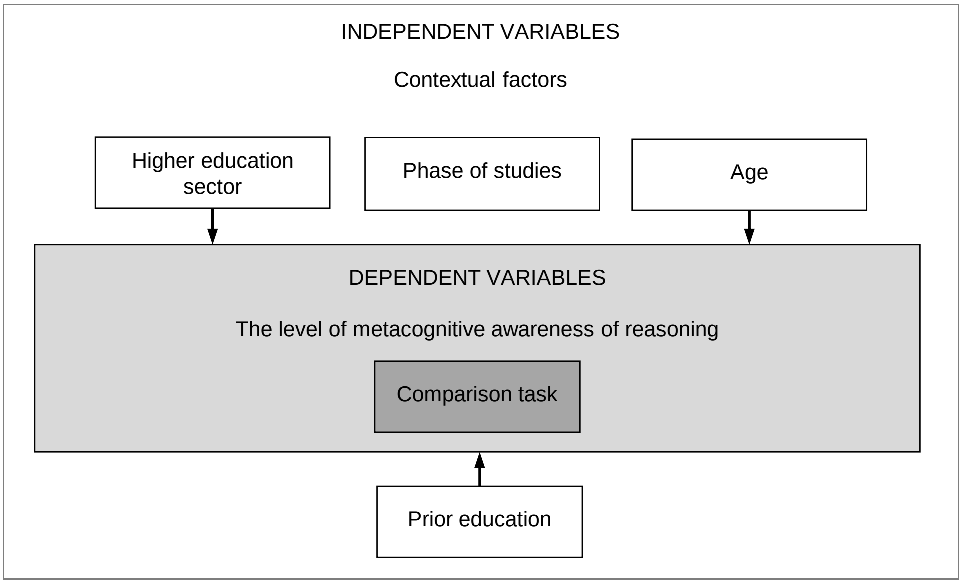

Figure 7. Factors affecting higher education students' metacognitive abilities measured in the Comparison task.

4.3 Conceptions of scientific thinking

This chapter presents the results to research questions 2.0, 2.1 and 2.2: "What are the students' conceptions of scientific thinking?", "Are there differences in the conceptions of scientific thinking between the higher education sectors" and "Are there differences in the conceptions of scientific between the study phases (initial, intermediate and final phase)?". Students' conceptions of scientific thinking were collected by the questionnaire using open-ended questions. Qualitative content analysis was applied to categorise and group the students' answers. The process of content analysis is described in more detail in Chapter 3.2.2.

The results are presented in the following order

1) First the contents of the categories of students' conceptions are described and the examples of students' original answers are presented. The number of students as well as the percentage values of the students representing the views is presented.
2) Second, students' conceptions at the two higher education sectors and at the different study phases are presented. Cross-tabulation is used to analyse the differences and the emphasis in the epistemological views of the two higher education sectors and different study phases. For the analysis of the significance of the differences between the groups the χ^2-tests (Pearson Chi-Square tests) are applied and the results are presented in the tables.

4.3.1 Students' conceptions of scientific thinking

The variety of students' conceptions of scientific thinking was broad. Students used 54 different definitions on scientific thinking in their answers, which were grouped in the analysis phase into 8 categories (including 4 subcategories). Students' conceptions of scientific thinking included both short and unambiguous expressions and more extensive, detailed and analytical definitions. Most of the students' conceptions were composed of more than one feature of scientific thinking. Consequently, in the results analysis each student can represent more than one view instead of representing only one category. In Table 36 the number and percentage values of the different conceptions of scientific thinking are presented.

Table 36. The number and percentage values of the different conceptions of scientific thinking.

Conceptions of scientific thinking	Number of students	% of all students (N=155)
Short expressions		
1. Objective	25	16.1
2. Critical	59	38.1
3. Fact-based	28	18.1
More extensive expressions		
4. Ability to use knowledge and theories		
4a) Apply knowledge	*51*	32.9
4b) Construct new knowledge based on existing knowledge	*32*	20.6
5. Extensive thinking including various perspectives	48	31.0
6. Use of scientific methods		
6a) Use of scientific research methods	*20*	12.9
6b) Logical thinking, causal reasoning	*38*	24.5
7. Creativity to form own conceptions (own way of thinking)	*31*	20.0
8. Other	*20*	12.9

Short expressions

The way to define scientific thinking by using very short expressions was typical for many students. The number of these expressions was one-third of all given definitions. This category included such views as scientific thinking is ‘objective thinking’, ‘critical and analytical thinking’ and ‘thinking, which is based on scientific knowledge and facts’. Students who made these definitions expressed their views briefly without providing hardly any or only short explanations or arguments for their views.

Critical and analytical thinking was mentioned most frequently (more than one-third of all students) as a key aspect in scientific thinking. According to the students’ views critical thinking included the ability to question and also think analytically and in an evaluative way. Also the expression ‘explorative way of thinking’ was used by the students. The following answers are typical examples of the conceptions of scientific thinking as critical and analytical:

> *To my mind scientific thinking involves objective and critical thinking. That is, you do not take all information as truth but instead you ask questions, even dumb ones. Theories are simply the best prevailing views as science evolves...* (UAS student, 125)

> *Questioning, questioning of sources, patience in drawing conclusions, some creativity as well. Analytical thinking and understanding wider contexts.* (University student, 14)

The category of *objective thinking* included very short definitions of scientific thinking as objective thinking and also mentions the importance of keeping one's own opinions, attitudes and emotions separate from scientific thinking. Some students mentioned the recognition and evaluation of the effects of one's own attitudes. The following answers are examples of conceptions of scientific thinking as objective thinking:

> *Scientific thinking is drawing objective conclusions based on scientifically proven facts.* (UAS student, 96)

> *Scientific thinking is thoroughly studying and thinking of things/events, etc. while excluding opinions and assumptions. Issues are investigated scientifically without personal bias, assumptions, etc.* (UAS student, 82)

One part of the students defined scientific thinking as *thinking which is based on facts*. This perspective emphasised the view that scientific knowledge should be based on facts, which are true or proved to be true by the rules of research/inquiry. The use of theoretical concepts in thinking was also mentioned. This category also included the views that scientific thinking is highly abstract or, by contrast, very exact. The following answers are examples including the conceptions of scientific thinking as thinking, which is based on scientific knowledge and facts:

> *Scientific thinking is based on facts, studied and proven evidence of the state of affairs. Scientific thinking aims to question current truths. Questioning should be based on facts, not opinions or feelings. Scientific thinking views the context through its components, trying to understand their character and their interrelationships.* (University student, 153)

More extensive views and arguments

More extensive, detailed and analytical definitions of scientific thinking were presented in two thirds of all answers. The most common definition of scientific thinking among these more extensive answers referred to *the abilities to use knowledge and theories*. More than one-fifth of all students emphasised this view. According to the students' views these abilities also included the ability to apply theories and knowledge in different practical and real-life situations. In addition to the knowledge application view also *constructing new knowledge based on existing knowledge* as a key feature of scientific thinking was raised by many students. The construction of new knowledge was defined to occur when verifying the existing knowledge, by making syntheses and finding the core of the matter, by reducing knowledge to theories and models and by combining various knowledge entities.

> *Scientific thinking is about dealing with things from a theoretical perspective. Matters are often dealt with as rather separate from their environment thus thinking is rather theoretical. Scientific thinking is about piecing together cause-and-effect relationships and creating theories on the basis of those. Independent thinking and the ability to understand how things connect together are also scientific thinking.* (University student at the initial phase of studies, 24)

> *Here we have a man without money buying a cow. Yet one must try to say something. With the results of scientific thinking one maintains something old, good and tried and tested or creates something new and revolutionary. Maybe a sentence from law "innocent until proven guilty" contains something from the origins of scientific thinking. So we use something old until the new model is better or complements the earlier one. Scientific thinking is about problem solving, modelling, and understanding structures. It is based on earlier documented work and knowhow, which is a good basis for questioning and development.* (UAS student at the intermediate phase, 121)

Almost one-third of all students included in their conceptions of scientific thinking such definitions as *extensive thinking, comprehensive thinking and thinking which takes account more than one perspective.* These definitions stressed the ability to sketch things as a part of totalities, the ability to divide the whole into separate parts, the ability to find and define the problem and ask the right questions, the ability to separate the essential from the less essential (set things in order of importance), seeing things from versatile viewpoints/ knowledge sources and understanding and taking into consideration the possible effects of the context.

> *Scientific thinking is about understanding things in larger contexts and combining things. The relationships of the facts and background must be investigated and it must be interesting. In scientific thinking you must be prepared to alter your views on things and theories if evidence so suggests. Science changes and evolves continuously.* (University student at the initial phase of studies, 21)

> *The ability to combine facts, see beneath the surface and apply theory to practice. In addition, the ability to understand larger contexts, to be critical and the ability to both acquire and utilise/process information → produce new information. Justification: The ability to understand large contexts and applying things from different perspectives is essentially connected to scientific thinking and the creation of new information. A command of larger contexts is important as well as knowledge about information aids in relevant and critical thinking.* (University student at the initial phase, 222)

One view among the most common conceptions of scientific thinking was *the use of scientific methods*. Systematic logical thinking and causal reasoning abilities were emphasised most in this category. Students considered that this included understanding cause and effects as well as different relationships. As a sub-category the use of scientific research methods was also mentioned. This included the ability to carry a typical research project through different phases: to set the hypothesis, to use both qualitative and quantitative research methods and to follow the rules of scientific inquiry.

> *To a great extent scientific thinking is about logical deduction. On the other hand it is also about creativity – the courage to create new constructs. Certain laws which must be followed to obtain credible results apply to scientific thinking.* (University student at the final phase on studies, 254)

> *In my opinion scientific thinking is about the continuous search for different ways of thinking and thinking models by reflecting on old knowledge and new understanding, and by looking for justification using various commonly accepted methods. Thinking is in a constant mode of change but may be very deterministic, thus the usefulness of the methods and their suitability may not be questioned. The end result is poor science if not real new information is obtained.* (UAS students at the initial phase of studies, 119)

Creativity in forming one's own perspectives and conceptions/opinions was emphasised as a feature of scientific thinking by approximately twenty percent of all students. These students found it important in scientific thinking to be able to and have motivation to think in a creative way, to think by oneself and independently, to gain a deeper perspective and to have enthusiasm in thinking and an inquisitive approach in order to learn and understand.

> *Scientific thinking is about studying things and establishing your own opinions based on your own research.* (University student at the initial phase of studies, 256)

> *Scientific thinking is about evaluating and comparing your own and others' thinking, drawing conclusions and creativity. If you are able to justify new/your conclusions by using scientifically acceptable methods and language, you will be accepted in the scientific community.* (University student at the final phase of studies, 301)

Six percent of all definitions were mentioned infrequently and for this reason were categorised as *other expressions*. This category included such views of scientific thinking as metacognitive abilities to identify one's own thinking processes, communications skills, interaction within the academic community, technical skills in acquiring knowledge, patience in thinking, everyday thinking and using one's common sense in thinking.

4.3.2 Differences in the conceptions of scientific thinking between the university and UAS students

Students at the two higher education sectors had different ways to define scientific thinking (see Table 37). Among the students in the university sector the most typical definitions of scientific thinking were the following five: critical thinking, extensive thinking with various perspectives, logical thinking and causal reasoning, ability to apply knowledge, and ability to construct new knowledge. Each of these was mentioned by at least a quarter of all students. University students defined scientific thinking significantly more frequently than the students in the other sector as critical thinking, as an ability to construct new knowledge, and as logical thinking (see Table 37).

Students in the UASs had in their top five list the same three definitions of scientific thinking as the university students had: critical thinking (however, the difference in emphasis between the sector was significant), the ability to apply knowledge and extensive thinking with multiple perspectives. Among the UAS students' frequently mentioned definitions of scientific thinking was also objective thinking and thinking which is based on proven facts. The last mentioned definition was used very rarely by university students and in this sense the difference between the sectors was significant (see Table 37).

Table 37. Cross-tabulation of the views on scientific thinking and higher education sectors. Number of students behind each expression, percentage value of all students within the sector and differences in conceptions between the UAS and university students.

Conceptions of scientific thinking	Higher education sector				Both sectors		χ^2
	University students		UAS students				
	n	% of all university students (n=96)	n	% of all UAS students (n=59)	N	% of all students (N=155)	
Short expressions							
1. Objective	14	14.6	11	18.6	25	16.1	χ^2 =.445; df=1; p=ns
2. Critical	46	47.9	13	22.0	59	38.1	χ^2 =10.384; df=1; p<.01
3. Fact based	10	10.4	18	30.5	28	18.1	χ^2 =9.966; df=1; p<.05
More extensive expressions							
4. Ability to use knowledge and theories							
4a) Apply knowledge	30	31.3	21	35.6	51	32.9	χ^2 =.321; df=1; p=ns
4b) Construct new knowledge based on existing knowledge	26	27.1	6	10.2	32	20.6	χ^2 =.381; df=1; p<.05
5. Extensive thinking including various perspectives	35	36.5	13	22.0	48	31.0	χ^2 =3.557; df=1; p=ns
6. Use of scientific methods							
6a) Use of scientific research methods	12	12.5	8	13.6	20	12.9	χ^2 =.036; df=1; p=ns
6b) Logical thinking, causal reasoning	31	32.3	7	11.9	38	24.5	χ^2 =.381; df=1; p<.05
7. Creativity to form one's own conceptions	21	21.9	10	16.9	31	20.0	χ^2 =.554; df=1; p=ns
8. Other	13	13.5	7	11.9	20	12.9	χ^2 =.091; df=1; p=ns

4.3.3 Differences in the conceptions of scientific thinking between the different phases of studies

Students at the different phases of studies within each sector had rather similar ways to view the concept of scientific thinking (see Table 38). The higher education sectors within each phase differentiated from each other in some dimensions, but the differences between the initial, intermediate and final phases within the sectors were small. On the base of these results it seems that the differences in conceptions of scientific thinking were bigger between the higher education sectors than between the phases within the sectors (the results of the two higher education sectors are presented in the Chapter 4.3.2).

The three categories with the highest frequencies among the initial phase students in both sectors emphasised the ability to apply knowledge and to think in a broad-ranging way with multiple perspectives. The difference between the sectors at the initial phase was that university students emphasised more the role of critical thinking and the ability to construct new knowledge while UAS students stressed more thinking which is based on facts and the use of scientific research methods (the rules of scientific inquiry).

The intermediate phase students in the two sectors shared the view of scientific thinking as critical and analytical thinking as one of the most popular conceptions. In the university sector among the three most popular views were also extensive thinking with various perspectives and the role of logical and causal thinking. With the UAS students among the three most typical expressions were (in addition to critical thinking) fact-based thinking and the ability to apply knowledge.

At the final phase the two sectors shared the view of scientific thinking as extensive thinking with multiple perspectives. In addition to this view, in the list of the three most popular views in the university sector were critical thinking and the ability to construct knowledge, while in the other higher education sector the most frequently mentioned views were objective thinking and the ability to apply knowledge.

In both higher education sectors the differences between the initial phase and the final phase were small. In both phases the university sector students emphasised most critical thinking, extensive thinking with multiple perspectives and the ability to use knowledge and theories. At the UASs to apply knowledge and extensive thinking were among the three most popular views both at the initial phase and at the final phase. In UASs there was a difference between the initial and final phase concerning the number of expressions referring to the importance of fact-based thinking. Students at the final phase emphasised objectivity in scientific thinking more.

The six different study groups (initial, intermediate and final students in the university sector and polytechnic sector) differentiated significantly from each other in their emphasis on three views: scientific thinking as critical thinking ($\chi^2 = 18.683$; df=5; $p<.01$), scientific thinking as fact-based thinking ($\chi^2 = 14.474$; df=5; $p<.05$) and as an ability to construct new knowledge ($\chi^2 = 14.280$; df=5; $p<.05$).

Table 38. Cross-tabulation of the conceptions of scientific thinking and different phases of higher education studies in universities and UASs. Number of students behind each expression and percentage value of all students within the study phase.

Conceptions of scientific thinking	Phase of studies														All students N= 155	
	Initial phase				Intermediate phase				Final Phase							
	University students n=33		UAS students n= 34		University students n=8		UAS students n=20		University students n=17		UAS students n=43					
	n	%	n	%	n	%	n	%	n	%	n	%			N	**%**
Short expressions																
1. Objective	4	12.1	3	8.8	2	10.0	2	25.0	8	18.6	6	35.3			25	16.1
2. Critical	12	36.4	7	20.6	7	35.0	3	37.5	27	62.8	3	17.6			59	38.1
3. Fact based	2	6.1	12	35.3	1	5.0	3	37.5	7	16.3	3	17.6			28	18.1
More extensive expressions																
4. Ability to use knowledge and theories *4a) Apply knowledge* *4b) Construct new knowledge based on existing knowledge*	11 9	33.3 27.3	12 1	35.3 2.9	5 2	25.0 10.0	4 2	50.0 25.0	14 15	32.6 34.9	5 3	29.4 17.6			51 32	32.9 20.6
5. Extensive thinking including various perspectives	10	30.3	9	26.5	8	40.0	-	-	17	39.5	4	23.5			48	31.0
6. Use of scientific methods *6a) Use of scientific research methods* *6b) Logical thinking, causal reasoning*	- 9	- 27.3	6 4	17.6 11.8	3 8	15.0 40.0	1 1	12.5 12.5	9 14	20.9 32.6	1 2	5.9 11.8			20 38	12.9 24.5
7. Creativity to form one's own conceptions	5	15.2	7	20.6	6	30.0	-	-	10	23.3	3	17.6			31	20.0
8. Other	6	18.2	5	14.7	4	20.0	1	12.5	3	7.0	1	5.9			20	12.9

4.4 The connections between the two approaches of scientific thinking

4.4.1 Students' logical-epistemological profiles in universities and UASs

One of the aims of this study is to explore the possible connections between logical thinking skills and epistemological beliefs on knowledge and knowing (research question 3) The cross tabulation of the views on scientific thinking and the level of logical thinking skills was applied to analyse the possible connections between these two approaches of scientific thinking. For this analysis all the students were categorised into two groups by the level of their logical reasoning abilities (i.e. by the results of the Scientific Reasoning Tasks, see Chapter 4.1). Students were categorised into the 'formal reasoning stage' group if they had shown formal reasoning abilities (3A-3B*) in both reasoning tasks, the Chemical and Pendulum tasks. If in one task or in both tasks the results had been under the formal stage (2A-2B*), students were categorised in this analysis in the group 'prior to formal reasoning stage'. The number of students in the two sectors in these two reasoning groups are presented in Table 39.

Table 39. The number of students in the two stages of reasoning within the two sectors.

Higher education sector	Level of logical thinking		
	Formal reasoning stage	Prior to formal reasoning stage	Total
University	57	39	96
UAS	21	38	59
Total	78	77	155

Students with the formal stage reasoning abilities emphasised most the three following conceptions of scientific thinking: critical thinking, the ability to apply knowledge and logical thinking/causal reasoning. All these three views were mentioned by more than a third of the students (see Table 40).

The profile of students who were categorised in the group 'not reached the formal stage' was partly similar to the formal group. Critical thinking and and ability to apply knowledge were shared conceptions among the three most emphasised views. In addition to these, students who did not reach the stage of formal abilities stressed also extensive thinking with multiple perspectives and thinking which is based on proven facts.

Statistical differences between the two reasoning groups were found in the emphasis on the ability to apply knowledge and logical thinking (see the Table 40.). These two views were emphasised more among the formal stage students.

Table 40. Cross tabulation of the views on scientific thinking and the level of causal reasoning (formal stage/prior the formal stage). The number of students providing each response, percentage value of all students within the level of reasoning and differences in conceptions between the students at the formal operational stage of reasoning and students at lower level reasoning skills.

Conceptions of scientific thinking	**Level of logical thinking**				**All students (N=155)**		χ^2
	Formal reasoning stage (n=78)		**Prior to formal reasoning Stage (n=77)**				
	n	%	n	%	N	%	
Short expressions							
1. Objective	14	17.9	11	14.3	25	16.1	χ^2 =.384; df=1; p=ns
2. Critical	35	44.9	24	31.2	59	38.1	χ^2 =3.086; df=5; p=ns
3. Fact based	11	14.1	17	22.1	28	18.1	χ^2 =1.665; df=1; p=ns
More extensive expressions							
4. Ability to use knowledge and theories							
4a) Apply knowledge	34	43.6	17	22.1	*51*	32.9	χ^2 =8.122; df=1; p<.01
4b) Construct new knowledge based on existing knowledge	17	21.8	15	19.5	*32*	20.6	χ^2 =.127; df=1; p=ns
5. Extensive thinking including various perspectives	21	26.9	27	35.1	48	31.0	χ^2 =.1.202; df=1; p=ns
6. Use of scientific methods							
6a) Use of scientific research methods	11	14.1	9	11.7	*20*	12.9	χ^2 =.201; df=1; p=ns
6b) Logical thinking, causal reasoning	26	33.3	12	15.6	*38*	24.5	χ^2 =6.596; df=1; p<.01
7. Creativity to form own conceptions (own way of thinking)	19	24.4	12	15.6	31	20.0	χ^2 =1.861; df=1; p=ns
8. Other	10	12.8	10	13.0	20	12.9	χ^2 =.384; df=1; p=ns

4.5 Students' experiences of thinking and learning in the field of business and administration in the two higher education sectors

One of the theoretical assumptions in this study was that the aims and values of the two higher education sectors as well as disciplinary specific aims, values and knowledge structures have an effect on students' thinking, epistemological assumptions and learning (see e.g., Lampinen, 2002; Söderqvist, 2004; Ylijoki, 2000; Neuman et al., 2002; Lindblom-Ylänne et al., 2006). Students' experiences and views on learning in the two sectors were collected in order to analyse the effects of the different contexts and requirements in the two sectors on the students' thinking.

This chapter presents the students' answers to the questions concerning the thinking and skill-requirements for studying in the two sectors and also students' experiences on how scientific thinking is promoted in higher education studies.

4.5.1 Students' conceptions of skill requirements in universities and UASs

In order to explore the profiles of higher education studies in the two higher education sectors, students were asked to tell about their experiences concerning thinking requirements as well as other skills needed in studies in their own institution. This information was important to be able to analyse and compare the role of scientific thinking in studies in the two higher education sectors from the students' perspective. The two sectors are different in their teaching and learning aims and in their notions of learning based on scientific knowledge, but in certain respects there is overlap. Students' views and experiences of teaching and learning were aimed to provide useful information on the balance and roles of the two sectors.

Concerning the study of logical thinking, 155 out of a total sample of 388 students answered the question concerning the experiences of requirements for studying in higher education. Students' views were categorised by applying the method of qualitative content analysis (see Chapter 3.2.3). The results are presented in tables, where the number of students representing a certain view is mentioned. Statistical differences between the sectors are analysed by using χ^2-tests (Pearson Chi Square).

The results indicate different emphases in the two higher education sectors in the students' experiences of the skills needed in higher education studies (see Table 41). The largest category concerning the requirements for studying in higher education was *academic thinking skills*, which was mentioned by almost 50% of all students. Especially among university students these thinking skills were mentioned very frequently and in this sense the statistical difference between the sectors was significant. Further, the category of academic thinking skills was divided into three sub-categories to analyse more carefully students' views concerning requirements for thinking. The sub-category of *critical, analytical and creative thinking* also included such abilities as metacognitive skills, general thinking skills, conceptual thinking and the ability to form one's own views and conceptions. These requirements for thinking were emphasised more often by the university students and the difference between the emphases in the sectors was statistically significant. The other two sub-categories of academic thinking skills were *logical reasoning/problem solving and knowledge application.* These were stressed equally among the students within the two sectors.

Knowledge acquisition and construction was the second largest category and like the academic thinking skills, these abilities were mentioned by almost half of the whole student group. This category also included abilities of knowledge processing and forming ”the big picture”. University students emphasised these requirements significantly more than UAS students.

The category of *students' active role, motivation and self-guidance* was among the three most frequently-mentioned requirements in the whole student group. Also the ability to show initiative, diligence and to be able to concentrate and work under stress and pressure were mentioned by the students. More than a third of the university students mentioned features included in to this category, which was significantly more than among UAS students.

The last two categories of students' experiences of higher education requirements were *generic skills* and *subject knowledge/theoretical knowledge*. As generic skills students mentioned co-operation skills, the ability to learn, studying techniques, articulacy and writing skills, and good memory. These skills were emphasised especially among the UAS students. The category of subject knowledge included theoretical knowledge, mathematics, languages and common knowledge. Four students answered that *no special skills are needed* in higher education studies – the use of common sense is sufficient.

Table 41. Cross tabulation of the views on requirements for studying in higher education at the two sectors and the differences between the sectors.

Requirements for studying	Higher education sector						
	University students (n=96)		UAS students (n=59)		Both sectors (N=155)		
	n	%	n	%	N	%	χ^2
1. Academic thinking skills	55	57.3	19	32.2	74	47.7	χ^2 =9.219; df=1; p<.01
1a) Critical, analytical and creative thinking	43	44.8	10	16.9	53	34.2	χ^2 =12.589; df=1; p<.001
1b) Logical reasoning and problem solving	16	16.7	8	13.6	24	15.5	χ^2 =.270; df=1; p=ns
1c) Knowledge application	12	12.5	7	11.9	19	12.3	χ^2 =.014; df=1; p=ns
2. Student's active role, motivation and self- guidance	41	42.7	15	25.4	56	36.1	χ^2 =4.731; df=1; p<.05
3. Subject knowledge, theoretical knowledge	13	13.5	6	10.2	19	12.3	χ^2 =.386; df=1; p=ns
4. Knowledge acquisi-tion and construction	55	57.3	18	30.5	73	47.1	χ^2 =10.512; df=1; p<.01
5. Generic skills	27	28.1	12	30.3	39	25.2	χ^2 = 1.176; df=;1 p=ps
6. No need of special skills	3	3.1	1	1.7	4	2.6	χ^2 =.297; df=1; p=ns

4.5.2 Students experiences on how scientific thinking is promoted in higher education

In order to extend the understanding of students' conceptions and experiences of higher education studies, one further theme concerning the role of scientific thinking in studies was added to the enquiry of my study. 143 out of 155 students (the total sample of the enquiry data) answered to question "Do the studies in your university/UAS promote the development of scientific thinking?" and "If so, how is scientific thinking promoted?" and "If not, why do studies not promote scientific thinking?"

The experiences of the enhancement of scientific thinking in studies were different in the two sectors (χ^2 =29.941; df=6; p<.001). 85% of the university students answered that scientific thinking is promoted, while the number of positive answers in the other sector was 61%. Among the students at the UASs a third had the experience that their studies do not promote scientific thinking (see Table 42).

Table 42. Students' experiences concerning the emphasis on scientific thinking in higher education.

Is scientific thinking promoted in higher education studies?	Higher education sector				Both sectors (N=143)	
	University students (n=92)		UAS students (n=51)			
	n	%	n	%	N	%
1. Scientific thinking is promoted	67	72.8	27	52.9	94	65.7
2. Scientific thinking is promoted, but only slightly	11	12.0	4	7.8	15	10.5
3. Scientific thinking is not promoted	7	7.6	15	29.5	22	15.5
4. No opinion	7	7.6	5	9.8	12	8.3
Total	92	100	51	100	143	100

Although the students' views on the effects of teaching and learning on the scientific thinking in the two sectors differed from each other, interestingly the students in the both sectors with positive experiences of support had rather similar views on how studies have enhanced the development of scientific thinking (see Table 43). Students mentioned learning methods most frequently as an effective factor in the development of thinking. Problem-based learning, project works and case studies among the other co-operative and interactive learning methods were mentioned as effective methods. However, the role of independent learning and studying alone were also mentioned as important learning methods, which can have a positive effect on thinking development. Many students even emphasised that scientific thinking is a prerequisite for studying in higher education. They argued that one's own thinking, construction of knowledge, reasoning skills, understanding of cause and effects and the ability to make conclusions are abilities that are evident elements of studies. The final phase of studies and master's thesis/diploma work was also among the three most emphasised supportive factors.

Students also had positive experiences of the effects of teachers' orientation to teaching and styles and methods in teaching. In their opinion, teaching in their institution had fostered critical and analytical thinking and thinking with multiple perspectives. Some students also stressed the role of subject studies and the theoretical content of courses as having a positive effect on the students' scientific thinking. Some students also mentioned courses in research methodologies and argumentation. Some differences in the emphasis between the different categories appeared, but generally students in the two sectors had quite similar views on support given to scientific thinking and no significant differences between the sectors was apparent.

10 out of 22 students with negative experiences provided reasons for their views. Students, who had an experience that studies do not promote the development of scientific thinking presented the following views: it is not possible in studies to doubt or question, there is not enough space for one's own thoughts, knowledge is given as facts and there is not enough working in groups or co-operation.

Table 43. How scientific thinking is promoted in the two sectors.

In what way scientific thinking is promoted?	Higher education sector				Both sectors (N=155)	
	University students (n=96)		UAS students (n=59)			
	n	%	n	%	N	%
1. The final phase of studies, Master's thesis/diploma work	17	17.7	5	8.5	22	14.2
2. Methodological studies, courses of scientific thinking and argumentation	9	9.4	1	1.7	10	6.5
3. Subject studies and course contents	14	14.6	4	6.8	18	11.6
4. Orientation in teaching, teaching methods	5	15.6	4	6.8	19	12.3
5. Learning methods	16	16.7	7	11.9	23	14.8
6. Scientific thinking is a prerequisite for studying	13	13.5	9	15.3	22	14.2
7. Other	3	3.1	1	1.7	4	2.6

5 DISCUSSION

The aim of this doctoral thesis was to investigate students' scientific thinking skills, more precisely logical thinking and conceptions of scientific thinking in different contexts in higher education: in universities and UASs, in three different phases of studies, and in the field of economics and business administration. In addition, the purpose was to develop a theory of scientific thinking by exploring the connections between the students' logical thinking skills and their epistemological beliefs on knowledge and knowing. The most important findings of this study are discussed in the following chapter by linking the findings with the previous research of this field.

5.1 Logical thinking skills and metacognitive awareness of thinking

In this study the framework of exploring students' logical thinking skills focused on causal reasoning and metacognitive awareness of the reasoning process. The hypothetico-deductive reasoning process and its three sub-reasoning processes were used as indicators of the abilities of causal reasoning. The analysis of metacognitive awareness focused on the abilities to specify, reflect on and analyse the logical thinking process.

Logical thinking skills

The results of logical thinking skills showed that the higher education sector, prior education and the student's age have an influence on the reasoning skills of higher education students.

The results showed that the university students' skills proved to be more advanced than the skills of the UAS students. Results indicated that 60-80% of the university students reached the stage of formal operational thinking (3A-3B*), which means that their reasoning skills were at the level that is required in hypothetico-deductive thinking and in logical thinking, whereas only 50-60% of the UAS students reached this level. The result of students' reasoning thinking skills in higher education is comparable with the results of Kallio (1998): in her research sample 77% of students had reached the stage of formal operational thinking (3A-3B*). The results of the earlier studies among Finnish university students have indicated that only 55% of the students have reached the stage of formal operational thinking (Hautamäki, 1983).

In addition to the sector effect, students' age and prior education proved to have an influence on logical thinking skills. In the university sector the students at the age of 24 and over scored higher than younger students in the task measuring logical deduction and constructing and using formal models (Chemicals task). In the UAS sector, the reasoning skills among the oldest students were not better than among the younger ones. Finally, the results showed that among all students the upper secondary vocational education as a prior education seemed to indicate weaker reasoning abilities than the general upper secondary education (matriculation examination) or a Bachelor's degree as a prior education. Especially in the university sector, upper secondary vocational education as a prior education was typical for students with poor success in the reasoning tasks.

One of the theoretical assumptions in this study was that students' scientific thinking skills develop during their studies. However, the results did not indicate clear development trends in logical thinking skills between the study phases. Thus, as a limitation of these results, it should be noticed that with the method applied in this study it was not possible to follow students' individual development during the studies. In addition, it should be taken into account that the development of thinking is not necessarily a linear process, and may contain both progressive and regressive components at the same time, which makes assessment difficult (Kallio, 1998; Kuhn, 2008). Having said that, in the research field of logical thinking there are some positive research results concerning development in reasoning skills during higher education studies. However, these results are documented in cases when students are guided by direct training to apply causal reasoning processes (Adey & Shayer, 1994; Kallio, 1998).

Interestingly, the result of the final phase UAS students was shown to be different from the other student groups. Contrary to the assumption that thinking skills develop during studies, the Chemical task (measuring logical deduction, and constructing and using formal models) indicated that the reasoning abilities in the final phase were weaker than the abilities of the initial and intermediate phase students. One possible reason for this result can be found in the interruption of studies and in the change of study place, which are common especially in the UAS sector. More than 25% of the UAS students change the studying place in the middle of studies and approximately 9% of these students move to the university sector (Stenström, Virolainen, Vuorinen-Lampila & Valkonen, 2012). According to Vuorinen (2001), one of the typical reasons for the interruption of studies in the field of business and administration in UASs has been the move to the university sector which in this educational field is even more typical than in other academic fields. It is probable that the students who move over to the university, are those with a stronger orientation to scientific thinking, whereas those with a weaker scientific orientation stay in UASs. Thus, interruptions may explain these results of the final phase students' group at least partly. The profile of the final phase group may also be affected by educational aims and traditions, which in the UASs emphasise the general skills of working life and professional knowledge (see Kotila, 2004). However, also in UAS studies and especially in the final phase of studies, academic thinking skills and self-direction skills would be needed in conducting diploma work (Rissanen, 2003).

In the light of the results of the clear differences between the sectors, but only small differences between the study phases, it can be concluded that the most prominent factors affecting students' reasoning skills are the different aims and profiles of the two sectors. Thus, the differences between the sectors might also be linked to the theoretical and practical profiles of higher education applicants in the two sectors. According to the research results of Vuorinen and Valkonen (2003), there is a strong link between the applicants' choice of educational sector and their previous success in studies. Their results prove that the more successful an applicant had been in their earlier studies, the more likely they were to apply to university (the higher the matriculation examination results students have, the more likely they are to apply to university studies). Further, they found that applicants' practically or theoretically focused educational orientation is the most powerful predictor of their choice of educational goal. In the UAS sector, approximately 70% of the students have the matriculation examination as a prior education, whereas the share in the university sector is over 95% (Stenström et al., 2012). In addition, in the field of economics and business administration the competition is tough in seeking admission to studying. Ahola and Kokko (2001) have explored the student selection processes in the field of economics and business administration in universities and have found certain characteristics that are typical for students who have succeeded in the student selection process. These charactersistics include, for example, that they considered themselves to be mathematically gifted and highly motivated. This research result concerning the mathematical orientation of university students introduces an interesting viewpoint into the analysis of my study, namely that the mathematical orientation of the university students in my study would probably have had an effect on the results concerning logical thinking.

Metacognitive awareness of the reasoning processes

Reflection on, and monitoring and management of one's thought, are metacognitive operations which are part of higher-order thinking processes. Thinking about thinking implies the potential for active self-directed management of thinking and the direction of cognitive resources in a consciously controlled way (Kuhn, 2008). Thus, metacognitive skills imply the potential for developing advanced reasoning skills (Demetriou & Bakracevic, 2009). In this study the results of the students' self-reflective abilities and metacognitive awareness of the reasoning processes were in line with the results for logical thinking. The same factors which differentiated students in their reasoning skills affect the students' metacognitive awareness, namely the higher education sector, age and prior education. However, contrary to the results for reasoning tasks, the phase of studies also seemed to have an effect on metacognitive abilities. In the university sector, the achievement of the final phase students was better than the other students' achievement. These results are in line with previous research, which have indicated a positive interaction between education and the development of metacognitive awareness (Demetriou & Bakracevic, 2009). In this study, as with logical thinking skills, metacognitive abilities showed a difference between the sectors, the students in the university sector reaching higher results. Only 44% of UAS students showed the metacognitive abilities of reflection and an analysis of the reasoning process (levels 3-6), whereas 58% of the university students achieved the same level of reflection and metacognition. These results are clearly weaker than those of Kallio (1998): in her studies 92% of the university students (major in psychology) showed advanced metacognitive abilities (levels 3-6). In my study, students' age also seemed to have an effect on the results: students aged 24 and over had better metacognitive abilities than those at a younger age. Prior education divided the student group in the following way: students with the Bachelor's or Master's degree showed better reflective skills of analysing the reasoning processes than students with other prior education.

5.2 Epistemological beliefs about knowledge and knowing

Students' epistemological beliefs about knowledge and knowing were explored by analysing students' conceptions of scientific thinking. The results showed that higher education students exhibited a wide variety of conceptions concerning scientific thinking. The most prominent conceptions were the definitions of scientific thinking as 'critical and analytical thinking', as 'the ability to apply knowledge and theories in different practical and real-life situations', and as 'extensive and comprehensive thinking with various perspectives'. Both critical thinking and comprehensive thinking with the ability to see things from various perspectives and to take into account different knowledge sources have connections to the ability to understand and cope with changing knowledge. These conceptions can also be seen as indicators of sophisticated epistemological beliefs, including the acceptance of the relativistic nature of knowledge (Hofer & Pintrich, 1997; Kuhn et al, 2000; Strømsø et al., 2008). Corresponding results of students' conceptions of scientific thinking have also been found in other studies. Kaartinen-Koutaniemi (2009) explored university psychology students' conceptions and showed that students typically emphasised academic thinking skills, critical thinking and the ability to take into account different perspectives in evaluating the knowledge.

In addition to the conceptions of scientific thinking as critical and analytical thinking, knowledge application and extensive thinking, students also emphasised the ability to construct new knowledge, creativity to form one's own conceptions, logical and causal reasoning, use of scientific research methods, objective thinking, and thinking which is based on proven facts. Objective thinking and fact-based thinking as key features of scientific thinking may reflect students' conceptions and experiences of scientific research and the academic world in general. The importance of keeping one's own opinions, attitudes and emotions separate from scientific thinking was typical in those students' answers which emphasised objectivity in scientific thinking.

Students' conceptions of scientific thinking reflected their learning environment and the culture of their discipline and higher education sector. Previous research shows that conceptions of knowledge as well as processes of knowledge production vary in different disciplines, and that during their university years students tacitly learn the specific norms and culture of their discipline (Ylijoki, 2000). The relation between students' epistemological beliefs and their disciplinary environment, i.e. the characteristics of the curriculum and the nature of the discipline have also been analysed in several studies (e.g., Palmer & Marra, 2004; Kaartinen-Koutaniemi and Lindblom-Ylänne, 2008). Based on the results of this study, it seems that the most emphasised conceptions of scientific thinking reflect the aims and values of the business and administration field as a learning environment. According to Neumann and her colleagues (Neumann et al, 2002), it is typical for applied disciplines (into which economics and business administration can be classified) to place a strong value on the integration and application of existing knowledge and on the ability to apply theoretical ideas to professional contexts (problem-solving abilities). A wide knowledge base and the application of knowledge are also essential from the viewpoint of the growth of expertise (see, e.g., Hofer, 2001; Kaartinen-Koutaniemi, 2009). Kokko (2003) has underlined that especially in the field of economics and business administration there is a characteristic tension between academic and scientific, and professional and practical aspirations. Students' conceptions of scientific thinking seem to reflect this dichotomy: the conceptions of critical and analytical thinking are clearly linked to academic and scientific orientation, whereas knowledge application and extensive and comprehensive thinking using various perspectives can be connected to professional and practical orientations.

The balance between subjective and objective dimensions of knowing

In several theories of epistemological development the key aspect of development is the coordination of subjective and objective dimensions of knowing and the balance between them. According to the epistemic development models (e.g., Kuhn et al., 2000; King & Kitchener, 2002; Baxter Magolda, 1992, 2004), the primary task of epistemic development is a progression toward an integration of objectivity and subjectivity, a learning to coordinate one's own subjective perceptions and meaning making with the facts about ‘objective reality’, and knowledge of the authorities (see Hofer, 2002, 2006). Kuhn & Weinstock (2002) have claimed that the coordination of subjective and objective dimensions of knowing is the singular dimension that drives the progression of individual’s epistemic development. In my study, the balance between subjective and objective approaches in the students’ conceptions could be seen in students’ conceptions of justification processes and the individual’s roles in the construction of scientific knowledge. The most typical conceptions of scientific thinking emphasised the subjective role in knowledge construction and knowing: ‘critical and analytical thinking’, ‘the ability to apply knowledge and the ability to construct knowledge’, ‘extensive and comprehensive thinking applying various perspectives’ and ‘creativity in forming one’s own conceptions and opinions’. The emphasis of the objective approach to knowledge and knowing could be seen in answers in which the students concisely defined scientific thinking as ‘objective thinking’ and where scientific thinking was defined as being based on (unchanging) facts.

Dimensions of epistemic beliefs in students’ conceptions of scientific thinking

The results of this study showed that students constructed their definitions of scientific thinking by thinking of the issue from different viewpoints and by referring to the different elements of scientific thinking. In Hofer and Pintrich’s (1997) theory of personal epistemology, epistemic beliefs are divided into four dimensions: certainty of knowledge, simplicity of knowledge, source of knowledge and justification for knowing. The development of each dimension is seen as a continuum. Beliefs are organised into theories, instead of being a system of independent beliefs and it operates at the metacognitive level (Hofer & Pintrich, 1997; Hofer 2004a). Corresponding multidimensional models of beliefs are also applied by several other researches (e.g., Schommer, 1990; Buehl & Alexander, 2005, 2006; Strømsø et al, 2008).

In this study, the most typical way of defining scientific thinking referred to the certainty of knowledge and the justification for knowing. Students’ answers were typically based on the assumption that knowledge was tentative and evolving instead of seeing knowledge as certain and unchanging. Students emphasised knowledge evaluation through critical, analytical and logical thinking, as well as through comparing of multiple perspectives. The use of scientific methods and rules of inquiry were also frequently mentioned to constitute the elements of scientific thinking. The same features are found in sophisticated epistemological beliefs following the model of Strømsø, Bråten and Samuelstuen (2008), which is based on the theoretical work of Hofer and Pintrich (1997).

The definitions referring to the simplicity of knowledge and source of knowledge were also used in the students’ answers. Almost a third of all students included in their conceptions of scientific thinking such definitions as extensive thinking, comprehensive thinking, or thinking which takes account of more than one perspective. These conceptions were based on a view that knowledge is complex and consists of interrelated concepts. The ability to construct new knowledge, to make syntheses and reduce knowledge to theories and models, as well as creativity in thinking, the ability and willingness to think by oneself and gain a deeper perspective are indications of students' views on an individual's special role as an active constructor of knowledge. According to e.g., Strømsø, Bråten and Samuelstuen (2008) the conception of knowledge as a construction of individuals (in interaction with the environment) is a typical feature of sophisticated epistemological beliefs.

The only category in the results of this study which could be classified as reminiscent of less sophisticated epistemological beliefs (following the criteria presented by Strømsø et al, 2008), was the definition of scientific thinking as fact-based thinking and justification through authorities. These conceptions of thinking referred to the assumption that knowledge is transmitted from an external authority instead of containing personal judgments and interpretations and being actively constructed by individuals. Definitions like this were mentioned by 18% of the students.

Differences between the higher education sectors

The ways of defining scientific thinking were different in the two higher education sectors. University students defined scientific thinking statistically significantly more frequently as critical thinking, as an ability to construct new knowledge and as logical thinking. 'Thinking which is based on proven facts' was rarely used by the university students, unlike UAS students.

In the light of Hofer and Pintrich's (1997) dimensions of epistemological beliefs it seems that it is typical for university students to emphasise more the subjective approach to knowing, the role of the individual as a constructor of knowledge and justification for knowing through critical and logical thinking, whereas UAS students seem to emphasise more objectivity, and the use and application of existing knowledge and thinking which is based on externally justified knowledge.

The differences between the sectors seem to be connected to the different focuses and aims of the sectors. Students in the two sectors also have different orientations: practically or theoretically focused educational orientation is a powerful predictor of the student's choice between university and UAS studies (Vuorinen & Valkonen, 2003). In addition to students' orientation in the admission phase, the orientations of teaching and learning may affect students' thinking. In UASs, where applied research is emphasised, the attention is placed more on existing knowledge and the practical aims of knowledge application. In the field of economics and business administration, the aims of research are often practical also in the university sector (see, e.g., Kokko, 2003). In addition, the previous research has indicated (Vuorinen & Valkonen, 2003) that students' theoretical and scientific orientation in the field of economics and business administration is lower on average than in university studies. Moreover, the orientation is typically more theoretical and scientific and the aims of basic research are emphasised more in universities than in UASs (Lampinen, 2002). Interestingly, creativity as a key feature of scientific thinking was stressed in both sectors in a similar way. In both sectors, every tenth student included in their definitions of scientific thinking such features as 'to form one's own conceptions', 'to have motivation to create one's own views' and 'to have enthusiasm about thinking'.

Differences between the study phases

Students in the two sectors had different conceptions of scientific thinking, but within the sectors at the different phases of studies students' conceptions were rather similar, and the differences between the initial phase and the final phase were small. It can be concluded that significant changes in the students' conceptions of scientific thinking will not necessarily take place during the years of higher education studies. The result is in line with some other research results on university students' epistemological development, namely that development trends between the study phases have not been particularly evident (e.g., Bråten & Olaussen, 2005; Kaartinen-Koutaniemi, 2009). In this study the effects of the sectors on students' learning environments as well as the different profiles of students in the two sectors proved to be stronger than the effect of the number of studies in the sectors.

The result concerning the development of epistemological beliefs is contrary to the theoretical assumptions of this study. The number of years of schooling has been proved to be related to epistemological understanding in several researches (Perry, 1970; Baxter Magolda, 1992; King and Kitchener 1994; Weinstock, Neuman & Glassner, 2006). The studies of, for example, Lindblom-Ylänne (1999), Ylijoki (2000), Becher and Trowler (2001), Palmer and Marra (2004), and Kaartinen-Koutaniemi and Lindblom-Ylänne (2008) have shown students' epistemological development (the increase of divergence in epistemic beliefs) as the studies progress when epistemological differences have been compared between disciplines. These studies have indicated that students' personal epistemology in different disciplines is rather similar at the beginning of their studies, though differences appear as studies progress and students become members of their disciplinary cultures.

There are several aspects which make the assessment of epistemological development a challenging task. Hofer (2005) has explained that the development of personal epistemology is a cyclical rather than a linear process. Epistemological growth occurs in multidimensional ways, including also regression and recurrent thinking (Hofer, 2005). Further, theories on epistemological development suggest different factors which may have an impact on development. Both individual factors (e.g., the individual's level of expertise in a particular topic or domain, motivational and affective elements and the individual's self-regulation skills) and external factors (e.g. social and cultural factors and context) have been argued to play a role in explaining the development of epistemological beliefs (Sinatra & Pintrich, 2003; Bråten & Olaussen, 2005; see also Limón, 2006a). In this study, one reason for the UAS students' results might be the unfamiliarity of the domain of scientific thinking (see, Kuhn et al., 2000). Epistemological beliefs about knowledge and knowing are not necessarily similar in all domains, but variation in the sophistication of the conceptions may occur according to the familiarity and amount of the content knowledge of the domain. Concerning the reason for the state of research in an area of epistemic development and the effects of education, Weinstock (2009) has emphasised that more attention needs to be paid to what actually happens in school and in the educational context that promotes epistemological understanding.

5.3 The interaction between the two traditions of scientific thinking

One of the main aims of this study was to develop the theory of scientific thinking by exploring the connections between students' logical thinking skills and epistemological beliefs on knowledge and knowing. Research on adult thinking includes an analysis of the connections between epistemological beliefs and other cognitive abilities (i.e., argumentative reasoning skills, metacognitive thinking, critical thinking, use of study strategies, academic performance and knowledge construction) (e.g., Kuhn, 1991; King and Kitchener, 2004; Kitchener, King & DeLuca, 2006; Muis, 2008; Weinstock, 2009). However, published research focusing exactly on the connections between epistemological beliefs and logical thinking skills has been scarce.

On the base of the results of my study it can be concluded that the skills of logical thinking and the development of epistemological beliefs are connected together. The results showed that students with higher-level logical thinking skills emphasised more the abilities of knowledge application and logical thinking as key features in scientific thinking. These two conceptions of scientific thinking are linked to beliefs on the source of knowledge and to the ways of justifying knowing and representing sophisticated beliefs about knowledge and knowing (see, Hofer & Pintrich, 1997; Strømsø et al, 2008). Further, it seems that students with good reasoning abilities emphasised more the individual's active role in the knowledge construction and in constructing one's own perspectives. On the basis of the results, it can be assumed that good reasoning abilities promote the understanding of the individual's role as the source of knowledge and the process of justifying knowledge through the use of rules of inquiry. Conversely, the interaction might that sophisticated epistemological beliefs concerning the understanding of the individual's subjective role support the student's activity in applying reasoning skills to produce knowledge.

The role of metacognitive awareness as a shared factor behind both logical thinking skills and epistemological development is worth considering in developing the theory and concepts of scientific thinking. Just as the abilities to reflect on, monitor, and analyse the reasoning processes enhance logical thinking efficiency (e.g., Demetriou & Katzi, 2006; Demetriou et al., 2011), so too epistemic beliefs are shown to be related to reflection and self-regulation skills (e.g., Kuhn, 1991; Muis, 2008). Comparable conclusions on the connections between metacognitive abilities and logical thinking and epistemological development can also be drawn on the basis of the results of this study. This study has shown that it is characteristic for students with higher level logical thinking skills to have both advanced metacognitive abilities and sophisticated epistemological beliefs.

One other theoretical view to consider in explaining the connections between the two traditions of scientific thinking is Wellman's (1990) theory of mind (the individual's personal theory of epistemology), which includes the hypothesis that epistemological beliefs are an individual's theories about the nature of knowledge and the processes of thinking. According to Wellman's research, it does appear that if an individual makes a commitment to a particular epistemological stance, then he or she will perceive and think about his or her experience in a certain manner. Weinstock (2009) has also shown that epistemological understanding has an influence on the way one reasons.

5.4 Students' experiences of thinking and learning in higher education studies at the two sectors

Students' conceptions of skill requirements in higher education studies

One aim of this study was to explore the profiles of higher education studies by analysing and comparing the role of scientific thinking in studies in the two higher education sectors from the student's perspective. The results concerning students' experiences of the skills needed in higher education studies indicate differences between the two higher education sectors. Students in the university sector emphasised more academic thinking skills and especially the importance of critical, analytical and creative thinking as requirements for studying at university. The results are in line with the previous studies on university students' conceptions of qualification requirements. The results of Kaartinen-

Koutaniemi (2009), for example, showed that university students emphasised the importance of academic thinking skills and critical thinking in their studies. In my study university students also emphasised the skills of knowledge acquisition and construction. Further, they also stressed students' active role, motivation and self-guidance, including the abilities to show initiative, diligence and to be able to concentrate and work under pressure. Also the UAS students stressed the importance of knowledge acquisition and knowledge construction and also the student's own role and responsibilities in studies, but these requirements were emphasised even more among the university students. However, university students did not emphasise the importance of generic skills which were more stressed among the UAS students.

Students' views and experiences of teaching and learning provided interesting information in the sector profiles, indicating differences between the two higher education sectors. The findings concerning the views on teaching and learning in universities and UASs are in line with the results about scientific thinking in this study: differences between the sectors reflect the existence of the dichotomy between theoretical and practical orientation in studies (see also Kokko, 2003). The aims and traditions of research, in particular, are different in the two sectors, which also have an effect on the culture of teaching and learning in these sectors. At universities the pedagogical aims are typically linked to the growth of critical and analytical thinking as well as to the abilities of producing new knowledge (conducting scientific research). The result of this research showed that university students had adopted these aims and they also had an experience that these abilities are important in higher education studies. University students also emphasised the importance of the student's subjective role in acquiring and constructing new knowledge and creating new conceptions. The pedagogical approach in the UASs aims to underline especially the orientation of social and co-operative learning and shared expertise (Vesterinen, 2004). In this study students' at the UASs viewed generic skills as important skills in higher education studies. As generic skills they mentioned co-operation skills, the ability to learn to learn, studying techniques, articulacy, and good memory.

European business graduates have evaluated that innovative skills, analytical competencies, skills in working independently and problem-solving skills are the most important skills in working life. However, scientific skills, such as field-specific theoretical knowledge, knowledge of research methods, broad general knowledge and cross-disciplinary thinking, have proved to be important to only 50% of graduates (Kokko, 2003).

Students' experiences on how scientific thinking is promoted

The findings concerning the students' experiences on the extent of the support which is given to the scientific thinking development in their studies are in line with the other results of this study, namely that in all the findings of this study there are differences in students' views between the two sectors. Thus, in the university sector 85% of the students felt that scientific thinking (as they themselves had defined it) is supported. In the UASs 61% of the students considered that scientific thinking is supported and every third felt that the studies did not support scientific thinking at all. The difference between the sectors was statistically significant. The results are in line with the previous research by Kokko (2003), who has explored students' satisfaction with their studies in the field of economics and business administration and has shown that students found research-led teaching and opportunities to participate in research projects to be the most unsatisfactory areas in their education.

Although students' views on the effect of teaching and learning on scientific thinking in the two sectors differed from each other, interestingly the students in both sectors who had positive experiences concerning support had rather similar views on how studies had promoted the development of scientific thinking. Such learning methods as problem-based learning, project work, case studies and co-operative learning were most frequently mentioned by students as effective factors in the development of scientific thinking. The final phase of studies including the Master's thesis/diploma work was among the most emphasised supportive factor. Common to all these methods is the aim of linking theory with practice, which helps students to understand and create an integrated picture of scientific research with real-life connections. Students also stressed the role of subject studies, the theoretical content of courses as well as courses on research methodologies and argumentation. The role of the theoretical content and conceptions of one's own discipline in the growth of expertise during studies in higher education are also stressed by Ylijoki (2000). The significance and conceptions of methodology studies in the development of research skills has been studied by e.g. Lonka and Lindblom-Ylänne (1996), Murtonen and Lehtinen (2003), Murtonen (2005), and Murtonen and her colleagues (Murtonen, Iskala & Merenluoto, 2007). Based on the results of Murtonen and Lehtinen (2003), more attention should be paid in higher education studies to clarifying and understanding the meaning and goals of scientific research, e.g. by providing students with real-life research situations and concrete insights into the research process.

Students also had positive experiences of the effects of teachers' orientation on teaching and styles and methods in teaching. According to their opinion, teaching in their institution had fostered critical and analytical thinking and thinking with multiple perspectives. Other studies have also confirmed the contribution of the teachers' academic practices (i.e. teaching methods, practical training periods, supervision of Bachelor's and Master's theses) and preferences to the development of students' personal epistemology and scientific thinking (e.g. Neumann, 2001; Lueddeke, 2003; Palmer & Marra, 2004; Lindblom-

Ylänne et al., 2006; Kaartinen-Koutaniemi & Lindblom-Ylänne, 2008). Teachers' epistemological beliefs, pedagogical knowledge and their effects on teaching practices are explored in several studies (Fives & Buehl, 2008; Schraw & Olafson, 2002; Olafson & Schraw, 2006; Norton, Richardson, Hartley, Newstead & Mayes, 2005). In addition, the significance of the relationship between teaching and research as well as the effects of this relationship on teaching practices (i.e., research-led teaching), and students epistemological development have been evaluationed (Elen, Lindblom-Ylänne & Clement, 2007; Holbrook & Devonshire, 2005). In order to foster scientific thinking and an understanding of the scientific research of a discipline, more attention should be paid to learning what it means to know a field and how knowledge develops (Hofer, 2006).

The role of teaching is significant from the point of view of logical thinking. The training of hypothetico-deductive reasoning skills, skills in constructing 'controlled experiments' (identification and control of independent variables) and the ability to make rational assessment and conclusions on the basis of these experiment results can be taught e.g. in the context of methodology courses. There are also some research results which support the view that scientific thinking and logical thinking can be fostered through direct training at the different levels of education (Adey & Shayer, 1994; Kallio, 1998).

Students who felt that studies do not support the development of scientific thinking justified their views in the following ways: in studies it is not possible to doubt or question, there is not enough space for one's own thoughts, knowledge is given as facts and there is not enough working in groups or co-operation. Among others, Hofer (2006b) and later Kaartinen-Koutaniemi (2009) have underlined that in order to promote the development of personal epistemology in students, teachers should pay attention to such methods as argumentative debate, project work and cooperative learning.

6 VALIDITY AND LIMITATIONS OF THE STUDY

The challenges of this present study are related to the following issues: the use of two separate tasks to measure logical thinking, the method of exploring students' conceptions of scientific thinking, the sampling strategy, information on students' educational background and the lack of longitudinal data.

The use of two measures, the Science Reasoning Tasks called Pendulum and Chemicals, for investigating logical thinking entailed challenges to the analysis and the presentation of the results. The analysis of the data showed that the intercorrelation between the tasks was statistically significant, but because of the slightly different emphasis and foci of these tasks they were not combined into one measure. For this reason, unambiguous results of the students' level of logical thinking could not be obtained in this study. Instead, the tasks were analysed as parallel indicators of reasoning skills, and the specific descriptions of the skills investigated in each task were used in reporting the results (see Shayer & Adey, 1981; Kallio 1998).[16] However, from the point of view of validity, the use of different methods with the same object of study (methodological triangulation) is a method which does increase the validity. According to Cohen and his colleagues (Cohen et al., 2000), by a multi-method approach it is possible to avoid the risk of exclusive reliance on one method and a bias in the researcher's picture of the particular slice of reality she is investigating.

Students who participated in the Science Reasoning Tasks were able to receive their own results for the tasks afterwards by e-mail. This seemed to be an effective motivation factor for students and in this way it also increased the content validity of the study.

Researchers within the tradition of epistemological development have explored epistemological beliefs by using self-report questionnaires (e.g. in Schommer-Aikin's model), quantitative Liker-type scales and interview settings. Epistemological thinking skills, reasoning and underlying epistemological beliefs have been investigated through thinking-aloud procedures and problem-solving tasks (e.g. in King & Kitchener's Reflective Judgment models). However, in measuring pure epistemological beliefs, there are several challenges which are linked among other things to control of the domain-content and context influence (Limón, 2006). It can also be questioned whether epistemological beliefs, operating also at a metacognitive level can be measured (Hofer, 2004a; Limón, 2006).

[16] The Pendulum task measures primarily the schema when handling the variables (control and exclusion of variables), whereas the Chemicals task focuses also on formal models (logical deduction from the given premises and constructing and using formal models).

The use of a questionnaire in this study to explore students' epistemological beliefs about scientific thinking proved to provide both challenges and positive effects. The questionnaire included five open-ended questions concerning students' conceptions of scientific thinking, students' conceptions about how scientific thinking develops during the studies, how scientific thinking abilities are supported by their studies, and what kind of skills and competencies are needed in studies in universities and UASs. The challenges were related to the validity of the method. According to previous research, paper-and-pencil methods have not proved to be the most appropriate in exploring personal epistemology, although there are many advances in using them (i.e., cost, time and interpretation of results). Instead, qualitative methods and individual interviews have been shown to be more reliable in evaluating personal epistemology (Hofer & Pintrich, 1997; Hofer, 2004c; Muis et al., 2006). However, a questionnaire was used in this study because the aim was only focused on conceptions of scientific thinking, not on wider aspects of personal epistemology. In the case of my study, when rather direct questions were used, there is the possibility that responses concerning the concepts of scientific thinking have been based upon memorisation of information, which is based on study materials, instead of students' own personal opinions (see also, Kaartinen-Koutaniemi and Lindblom-Ylänne, 2008). Indirect questions may have resulted in more authentic individual answers. However, most of the students' responses in this study were rather long and the views were justified. The use of a questionnaire proved to be an appropriate method especially in exploring students' conceptions of the skill requirements in university and UAS studies and the role of scientific thinking in their studies. One of the limitations concerning the method was the shortness of the questionnaire and lack of methodological triangulation. Thus, it could have been possible to increase the validity of the study by adding more questions focusing on students' conceptions. The positive aspect relating to the use of a questionnaire was the possibility for students to answer the questionnaire by e-mail, which was clearly popular among the students. In addition, for students it was easy and quick to write longer responses to the questions.

One of the aspects which should be taken into account in the analysis of the results concerns the sampling strategy. The size of the total population in the field of economics and business administration is approximately 39, 000 students, of which 16, 000 are in universities and 23, 000 in UASs (source: Korkeakoulut 2011 – yliopistot ja ammattikorkeakoulut). In this study the sample was 388 students, which is sufficient from the point of the representativeness of the sample (see Cohen et al., 2000). The strategy of cluster sampling was applied in selecting the students for this study. A specific number of universities and UASs was selected and the student groups at different phases of studies were tested in those institutions. Cluster sampling is a valid strategy in cases where a simple random sample would pose difficulties because of a large and widely dispersed population (Cohen et al., 2000). However, the strategy of random sampling would have been the most useful from the point of view making generalisations about the whole population.

Another aspect worth considering in analysing the results is that since the data of the study was collected in 2004 the field of higher education teaching has been developed. This aspect should be borne in mind in making conclusions on the level of logical thinking and on the students' conceptions. Changes in teaching and learning methods and in curricula, for example, might have had an effect on these results if the study had been conducted today.

In analysing the results of the Science Reasoning Tasks and the questionnaire, the different profiles of the students who participated in these two measures should be considered. The comparison of the two data (the SRT and questionnaire) showed differences in students' age, gender, number of study credit and years of studies. Students who both answered the questionnaire and participated in the Science Reasoning Tasks, were older, had more study credits and had completed more study years.

The results of both the Science Reasoning Tasks and conceptions of scientific thinking showed statistically significant differences between the university and UAS students. In order to increase the validity of the conclusions based on this result, it would have been useful to have more information on the students' background, for example on prior academic success in secondary education.

One of the theoretical assumptions in this study was that students' scientific thinking skills develop and conceptions of scientific thinking change during the studies. The research design was constructed by selecting participants for the study from three different study phases and comparisons between the study phases were conducted. However, the results did not indicate clear development trends between the study phases either in logical thinking skills or in conceptions of scientific thinking. Thus, the conclusions on the lack of development of thinking on the grounds of these results can only be tentative because the method applied in this study was not longitudinal. Limón (2006) has stated that considering that personal epistemology would change with time and experience, longitudinal studies would be more appropriate to capture changes in epistemological beliefs.

The focus of this study was higher education students' scientific thinking in the field of economics and business administration. In constructing the research design the aim was to be to generalise the results for other fields of higher education. According to Becher (1994), in order to allow scope for better cross-fertilisation, researchers should take the disciplinary perspective fully into account. Thus, the social and academic context of the field of economics and business administration and of the two higher education sectors was taken into account. Factors affecting ways of scientific thinking were explored by analysing the differences in the aims, epistemological beliefs and characteristics of the learning environments in this field and in universities and in UASs. The identification of these effects increases the external validity of the research and enables the generalisation of the results to other higher education fields with corresponding profiles in the applied disciplines.

7 PRACTICAL IMPLICATIONS

The results of this study showed differences between the university and UAS students' scientific thinking in both logical thinking skills and conceptions of scientific thinking. The results indicated that 60-80% of the university students reached the level which is required in hypothetico-deductive thinking and causal reasoning, whereas only 50-60% of the UAS students reached this level. In the light of these results, more attention should be paid to the development of students' logical thinking skills both in the universities and in UASs. Further, the results showed that over 80% of the university students considered that scientific thinking was promoted in their studies, whereas only 60% of the UAS students agreed with this statement.

The role of scientific thinking and knowledge has strengthened in our society and in working life owing to the changes brought in by the information age. As skill requirements increase and working environments become more complex, the expectations concerning higher education are raised. The processes of redefining higher education degrees and curricula (e.g. the process of constructing the European Qualifications Framework, EQF[17]) as well as the discussion around generic skills are examples of the consequences of these changes in higher education. Traditionally, scientific knowledge and research have had a fundamental role as a basis for teaching and learning in universities and during the latest decade also in UASs. In the future, the role of research and R&D in UASs will be further strengthened by reform of the research and innovation strategies of education (the amendment of the UAS Act, which will come into force in 2014). Similarly, the role of university research will be revised and redefined as the importance of the scientific knowledge produced in universities is increasing as a core element in the economic growth (see, e.g., Ylijoki, Marttila & Lyytinen, 2012). Moreover, the promotion of the development of students' scientific thinking would bring with it other positive effects, such as enhancing other thinking abilities, learning approaches, self-regulated learning and the growth of expertise (e.g., Weinstock, 2009; Kuhn, 1991; Kitchener et al., 2006; Schommer, 1990;1993; Muis, 2008). In other words, the development of scientific thinking is a process encompassing the connections both to theoretical thinking and to professional development.

In order to promote the development of scientific thinking in students, special attention should be paid to the learning environment, teaching methods, social interaction and the stimulation of cognitive skills. The creation of a learning environment which enables students to discuss, argue and learn through co-

[17] For further information on the European Qualifications Framework, see www.ec.europa.eu/education.

operative methods and project work and to reflect upon their own learning are significant elements in the development of personal epistemology (Hofer 2006). Attention should also be paid to learning what it means to know in a field and how knowledge develops (Hofer, 2006). Therefore, in order to promote the development of advanced thinking skills, the focus should be on the critical evaluation of conflicting knowledge frameworks and on complex problem solving without single solutions (Kallio & Liitos, 2009). In addition, more emphasis should be paid to the abilities to create and use mental models and to self-management of thinking. Students must be directed towards generating, strengthening, and enhancing general reasoning patterns and problem-solving skills and managing mental resources (Demetriou et al., 2011). The results of this study have shown that many students find scientific research unfamiliar and their conceptions of scientific thinking were sometimes biased, for example absolute objectivity in scientific thinking was strongly emphasised by some students. In the light of these results, the relationship between teaching and research should be more foregrounded in teaching and different methods promoting this relationship should be applied (e.g., research-led teaching) (see also, Elen et al., 2007; Holbrook & Devonshire, 2005). In addition, the results indicated that differences between the sectors in scientific thinking might be explained by the different orientations and academic backgrounds of the students who seek admission to university and UAS studies. These differences should be taken into account in enhancing the students' development of scientific thinking especially in the UASs.

Researchers have also discussed the effects of salient factors on the development of thinking. Kuhn and her colleagues (Kuhn et al., 2000) have suggested that such factors would include the intellectual climate and values in modern culture and societies. Acknowledgement and acceptance of conflicting judgments and subjective views are crucial in this climate. This view encourages educators to pay attention to the climate in which students learn and develop their expertise in universities and UASs.

8 CONCLUSIONS

On the basis of the results of this study, the following conclusions can be made:

1. In universities 60-80% and in UASs 50-60% of the economics and business administration students possess thinking skills which are required in hypothetico-deductive thinking and logical reasoning. More than two-thirds of the university students have the metacognitive abilities to reflect on and analyse the reasoning process, whereas less than half of the UAS students reach the same level of metacognitive thinking.

2. Students' conceptions of scientific thinking reflect the characteristics of the field of economics and business administration. The conceptions of thinking as critical and analytical are linked to scientific and academic knowledge aspirations of the field, whereas knowledge application and extensive and comprehensive thinking adopting various perspectives are connected to professional and practical aspirations. University students' emphasise the role of the individual as a constructor of knowledge, involving the justification for knowing through critical and logical thinking, whereas UAS students emphasise more objectivity, and the application of existing knowledge and thinking which is based on externally justified knowledge.

3. The two approaches to scientific thinking, logical thinking and epistemological beliefs, are related. Students with advanced logical reasoning skills emphasise the subjective approach to thinking, the individual's active role as a source of knowledge and the construction of his or her own perspectives in thinking, as well as justification for knowing through the use of inquiry. Thus, advanced reasoning abilities make it easier for students to rely on a subjective approach to knowledge and knowing and, conversely, the subjective approach to thinking encourages and promotes students' activity in applying reasoning skills.

4. The differences in students' scientific thinking skills between the two higher education sectors are significant. Thinking skills, which are needed in causal reasoning, are more advanced among the university students. In addition, the skills of metacognitive awareness concerning the reasoning processes are better among the university students. Thus, the university students have more advanced logical thinking skills and, on the whole, better prerequisites for scientific thinking. The differences in the scientific thinking skills between the sectors are affected by the different educational aims and practices of the two sectors and by the theoretical and practical orientations of the students, which may affect

students' choices already in the phase of seeking the admission to university or to UAS studies. Therefore, in order to enhance scientific thinking in students, attention should be paid to the creation of a learning environment which enables students to gain concrete insights into the research processes and to discuss, argue and reflect upon their own thinking.

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APPENDICES

APPENDIX 1

THE PENDULUM TASK

NAME:

DATE OF TESTING: OF STUDIES:

FEMALE __ MALE __

(TOTAL SCORE:)

We are going to make a pendulum, using either

(1) a short (38 cm) or a long (95 cm) string;

(2) a light (100 g) or a heavy (400 g) weight;

(3) a gentle or a hard push.

A1-A2.

LENGTH WEIGHT PUSH N OF SWINGS

A1. EXP. 1.

Your guess__ SHORT HEAVY GENTLE

A2. EXP. 2.

Your guess__ TALL LIGHT GENTLE

A3. What effect do you suppose length, weight and push have on the number of swings in a half minute?

Length:

Weight:

Push:

A4A. What can you *conclude,* just from these experiments, about the effect of length, weight and push on the number of swings?

Length:

Weight:

Push:

A4B. Write down one more experiment that you think would be worth trying, and explain why you would carry out it. Also explain how this new experiment ties in with experiments 1 or 2:

A5. Imagine that we start again with experiment 1. Which other experiments would you use to test the effect of length on the number of swings? *(use as few experiments as possible; cross-out the experiments you don't need).*

A6. Again, starting with experiment 1. How would you test for the effect of weight?

A7. Imagine that someone performed these two experiments (*note that the experiments are carried out with another pendulum which was used in the former experiments*).

(L: long, W: heavy, P: strong (15)

(L: short, W: heavy, P: weak (20)

A7a. What do these experiments tell us about the effect of push?

A7b. If there are any other arrangements that you think you would need to be sure of the effect of push, write them next *(cross-out any of the original two arrangements that you don't need).*

B1-B4.

LENGTH WEIGHT PUSH N OF SWINGS

B1. EXP. 1 SHORT HEAVY GENTLE

B2. EXP. 2 LONG LIGHT GENTLE

B3. EXP. 3

Your guess___ TALL HEAVY STRONG

B4. EXP. 4

Your guess___ SHORT LIGHT GENTLE

B5. Now write down what these four experiments tell us about the effect of length, weight and push on the number of swings? For each factor, please write down only those experiments that you needed to use to arrive at a conclusion:

Length:

On which experiments is your conclusion based

Weight:

Based on experiments

Push:

Based on experiments

B6. Is the evidence weaker for determining the effect of any of the factors over the other factors?

If so, state which factor:

(a) and either show that the evidence is still sufficient;

(b) or explain why it is insufficient.

APPENDIX 2

SCORING OF THE PENDULUM TASK

(1) Give one point for every correct answer using the following rules for scoring, then, count the points together *as the total score.*

(2) Check from the table after these scoring rules to determine to which scale score the total score refers, and then classify the subject according to the corresponding developmental stage.

ITEM RIGHT ANSWER

A1-3 No scoring of these items.

A4a Length. Two types of answers are accepted: (a) The answers should be formulated as 'if it is longer, then...' For example: 'the longer the string, the more swings there are'. There is also another type of answer: (b) 'the effect of length cannot be determined, because all the required variables haven't been controlled in the experiments'.

A4a Weight and push: answer should show that the subject clearly understands that all the variables have not been sufficiently controlled to make valid conclusions. For example: 'You actually can't conclude anything, because the experimenter has changed two variables at the same time in the second experiment'.

A4b From the experiment it should be possible to conclude the effect of one variable in comparison with experiments A1 or A2. For example: 'With experiment A1 I would carry out another experiment, using a long string, a heavy weight and a light push' (i.e. the subject is here evaluating the effect of length). Or: 'With experiment A2 I would use a combination of 'short, light, weak'.

A5 Subjects have to give combinations of variables, where weight and push are controlled, and only length is varied. The following answers are acceptable: a) 'Long, heavy, light'. If there are any other suggestions, they should be crossed-out, or b) it is also acceptable if the subject gives another pair of valid experiments (e.g., 'short, light, weak' with the pair 'long, light, weak'), or c) thirdly, answers are also accepted where the subject gives another pair of valid combinations and crosses out the original experiments. But *do not* accept a list of three or more experiments where only the scorer is able to conclude that there is any sense linking them; the subject has to give a clear indication of a systematic pairwise comparison of experiments himself/herself.

A6 'Short, light, weak'. Otherwise, as for item A5. The Ss have to vary the weight, and at the same time control for the other variables.

A7a,A7b

1. The effect of push: 'One cannot conclude anything', or an answer where it is demonstrated that all the variables haven't been controlled sufficiently. 'You can't conclude anything about the push, because the length has been changed' or 'you

cannot conclude anything for sure, because it may be that length affects the number of swings';

2. Other experiments: 'long, heavy, weak' (in combination with the 1st experiment), or 'short, heavy, strong' (in combination with the 2nd experiment) and when required one of the above experiments should be crossed-out. We are looking for a valid pair of experiments, where only push is varied - for example 'long/heavy/weak', and which has to be evaluated with the first experiment. But also accept an answer in which a new pair of experiments is given, where only one variable is varied. But again, do not accept a list of three or more experiments where only the scorer is able to conclude that there is any sense linking them.

B3-4 No scoring of these items.

B5a-b 1. Length: accept an answer which claims that length has an effect. For example: 'short length - there are more swings and with a long string there seem to be fewer swings'. Subjects have to find the right effect of the variable, and they should also explicitly state the direction of the relationship.

2. Experiments B2 and B4. The answer is accepted *only if* the effect of length is correctly concluded. Note also that subjects must give only the pair '2 and 4'. No other pairs of experiments are acceptable.

B5a-b 1. Weight. Answers are accepted which state that weight has no effect on the number of swings (note: this conclusion is only possible if there are similar results in experiments B1 and B4, and also in B2 and B3).

2. Experiments B1 and B4. The answer is accepted only if the effect of weight is concluded correctly. No other answers are acceptable.

B5a-b To this question there is more than one way of answering:

(A) 1. The answer should state that push has no effect.

2. Experiments (B1 and B4) and (B2 and B3), both have to be mentioned. The answer is only accepted if the effect is correctly concluded.

(B) 1. 'The effect of push cannot be concluded' or that 'all the variables haven't been sufficiently controlled'.

2. Experiments (B1 and B4) and (B2 and B3), both have to be mentioned. The answer is only accepted if the effect is correctly concluded.

(C) 1. 'Push has no effect'.

2. Experiments B2 and B3 with the addendum of the assumption that weight has no effect.

B6 'Push'. The subject has to state either a) 'the other variables haven't been controlled for enough' or b) the subject shows that immediately after the effect of weight has been determined that the other variables are thus constant in B2 and B3, and from which the effect of push can be correctly concluded. Both B5/B6 have to be correct.

APPENDIX 3

DEVELOPMENTAL STAGE ACCORDING TO THE PENDULUM TASK

TOTAL SCORE	SCALE	SCORE	DEVELOPMENTAL STAGE AND SYMBOL
1	5.0	1-3	Full concrete operational (2B)
2	5.6		
3	6.0	4	Concrete generalization (2B*)
4	6.4		
5	6.7		
6	7.0	5	Early formal operational (3A)
7	7.2		
8	7.5		
9	7.8		
10	8.0	6	Full formal operational (3AB)
11	8.6		
12	9.0	7	Formal generalization (3B*)
13	10.0		

APPENDIX 4

THE CHEMICALS TASK

NAME:
DATE:
(TOTAL SCORE:)

EXPERIMENT 1. LIQUIDS A, B, L, M
1. Why do you think the liquid changed colour?

2. Do you think that the colour comes from either liquid L or B?
YES__ State from which liquid and why?
NO __ From where do you think the colour came?

Here you may give other explanations for the change in colour:

3. Write down all the mixtures of different liquids you would make to obtain again the pink colour (by using only the liquids shown on the video):

4. If there are any other combinations you would like to try to obtain the colour, please list them here:

5a. Based on the experiments you have seen, what do you think is the effect of liquid A on the forming of the colour?

5b. And what about liquid M?

5c. If somebody told you that liquid M is actually water, how would you examine this claim? Please state as thoroughly as possible what you would do in this situation, and using only the chemicals seen in the video. Explain also your reasons for doing so. (Please note: smelling the liquids or drinking them as 'experiments' are not accepted as answers!).

EXPERIMENT 2. LIQUIDS 1, 2, 3, 4 AND X

7. Imagine again that you are carrying out an experiment. Write down all those combinations of liquids which you would use to obtain again the same coloured liquid as in the video:

8. Are there any other combinations left to be made?

9. Can you say anything about what will happen if I mix liquids 1+2+X?
Please explain your answer:

10. Let's make the assumption that another person sees this and says: 'OK, this combination is necessary for the making of the colour, but it might be that there is no need to use all these liquids to make the colour'. State next the combinations of liquids you would use in order to evaluate if this person is right:

11. Another person says: 'This shows that you must use three liquids and X to obtain a coloured mixture of liquids'. Which combinations would you use to check if this person is correct in his conclusion?

12. State what are the fewest number of liquids needed to obtain the coloured liquid?
Tick the appropriate number: 1__, 2__,3__,4__,you can't say yet __
Give reasons for your answer:

13. Why do you think the liquid changed colour?

14a. Write down one combination of liquids with which you would study the effect of liquid number 4 on the formation of colour:

14b.Write down one combination of liquids with which you would study the effect of liquid number 2 on the formation of colour:

15. Evaluating the data you have been given, what would you conclude about the function of liquid number 2 on the forming of the colour?

On which combinations did you base this conclusion?

16. What conclusion would you make about the function of liquid number 4?

On which combinations did you base this conclusion?

17. Do you think that there is water in any of these glasses?

If your answer is 'yes', state in which glass, and explain how you can examine this assumption by using the liquids you have seen on the video. Write down also the combinations which you would use to study this hypothesis and five your reasons (Smelling/drinking are not valid as an answer!).

APPENDIX 5

SCORING OF THE CHEMICALS TASK

ITEM/ QUESTION	RIGHT ANSWER
1/ 1,2	The answers should be combinatorial: the cause of the colour is in the mixing of two liquids.
2/ 3,4	There should be at least 4 combinations of the following pairs: AL, AM, AB, BM and LM. If only coincidental (i.e. not systematic) combinations with three liquids are listed, the answer is not accepted.
3/ 5a-b	The following conclusions have to be made: (a) that liquid A inhibits colour in liquid L+B; (b) that the liquid M is irrelevant to the formation of the colour.
4/ 6	The following answers are acceptable: (a) to have shown the insight that there is an assumption in the question that water is a neutral liquid not affecting the formation of the colour; and (b) to list the experiments with which the subject would test the hypothesis. For example, the simplest way to demonstrate this is to give an answer such as 'I would add liquid M to all the other liquids and to all combinations of them, and if there is no change in the colour in any of the combinations, I would assume that M is water'.
5/ 7,8	2A: All single combinations 1+X, 2+X, 3+X and 4+X. 2AB: 2 or 3 pair combinations: for example 1+2+X, 2+3+X.
6/ 7,8	2B: 4 or 5 pair combinations.
7/ 7,8	2B3A: in question 7 and 8 all six pair combinations: 1+2+X, 1+3+X, 1+4+X, 2+3+X, 2+4+X, 3+4+X.
8/ 7,8	3A: in question 7 all above-mentioned pair combinations.
9/ 9	Subjects must refuse to answer. Stating (i) that it is not yet possible to reach a conclusion, or (ii) another way is to answer that the mixture might be with equal probability coloured or colourless; (iii) to claim that based on the experiments already made that there should be one liquid which inhibits colour.
10/ 10	The following combinations are accepted: 1+2+X, 2+3+X, 1+3+X.
11/ 11	Combination 1+3+X *only*; no other combinations accepted (i.e. one has to understand the logical implication).
12/ 12	The right answer is that no conclusion can be made yet. Answers are acceptable in which both two and three liquids at the same time are stated as the correct answer.
13/ 13	As item 1, question 1 and 2.
14/ 14a-b	The following answers are acceptable (a) 1+3+X+2; (b) 1+3+X+4.
15/ 15,16	The subject has to determine the effect of both chemicals. Liquid 2 has no effect on the formation of colour; liquid 4 inhibits the formation of the colour.

16/ 15,16 Subject has to refer to the combinations made earlier: (a) for the effect of liquid 2 the mixtures 1+2+3+X and 1+3+X; (b) and for the effect of liquid 4 the mixtures 1+3+4+X and 1+3+X.

17/ 17 As for item 4, question 6.

APPENDIX 6

DEVELOPMENTAL STAGE ACCORDING TO THE CHEMICALS TASK

TOTAL SCORE	SCALE	SCORE	DEVELOPMENTAL STAGE AND SYMBOL
1	3.66	1-2	Mid concrete reasoning (2AB)
2	4.55		
3	5.14	3	Full concrete operational (2B)
4	5.59		
5	5.97		
6	6.30	4	Concrete generalization (2B*)
7	6.61		
8	6.90		
9	7.18	5	Early formal operational (3A)
10	7.47		
11	7.76		
12	8.07	6	Full formal operational (3AB)
13	8.41		
14	8.80		
15	9.30	7	Formal generalization (3B*)
16	10.04		

APPENDIX 7

THE COMPARISON TASK

NAME:

DATE:

(TOTAL SCORE:)

Evaluate and compare the tasks you have just answered, i.e. the Pendulum and the Chemicals tasks. Give first your evaluation below by selecting which of the following three claims is correct from your point of view. After that give reasons for your selection on the next page, making sure to give as extensive description and statement of reasons as you can. You may use the last page of this task which has been intentionally left empty for you to create your own (e.g., symbolic) evaluation of the tasks.

1. How similar or different do you consider the tasks to be? You should focus on the thoughts which were on your mind during the answering process, and at the same time, please consider also the methods you used in solving them.

__ the tasks were clearly similar

__ the tasks were clearly different

__ the tasks had something in common, but there were also differences between them.

2. Now give your reasons as thoroughly as you can. How similar or different do you consider the tasks to be which you have just completed? You should focus on the thoughts which were in your mind during the answering process, and at the same time, please consider also the methods you used in solving them.

APPENDIX 8

SCORING OF THE COMPARISON TASK

1. LEVEL OF NO REFLECTION

There is no indication in the answer that the subject has consciously reflected on the thought-processes used in the tasks. Subjects who fulfil the following criterion are included in this category:

- they evaluate the tasks using dimensions of easiness/hardness, e.g., 'the Chemicals task was harder than the Pendulum task';
- they evaluate their own emotions and feelings towards the tasks, but not evaluating their cognitions, e.g., 'I didn't like these tasks at all', or 'I don't like logical/mathematical/scientific tasks at all';
- all other subjective evaluations and 'nonsense' answers are placed in this category.

2. LEVEL OF REFLECTION OF THE CONTENT OF THE TASKS

Subjects give indications that they have evaluated the manifest content of the tasks, i.e. the phenomenal features of the tasks are given in their evaluations. Subjects who fulfil the following criteria are included in this category:

- evaluation of the tasks is focused on their similar or different features, e.g., 'this task is from the field of chemistry and the Pendulum task from the field of physics', ' these tasks remind me of tasks of chemistry and physics in high school';
- evaluation of the content of the task based on vague characteristics of reasoning (but *not* based on logical operations of reasoning), e.g., =a mathematical and abstract way of reasoning is needed in these tasks' or 'these are tasks where conclusions are needed' or 'both tasks measure logical capabilities'.

3. LEVEL OF DEVELOPING GENERAL ANALYSIS

The key indicator here is that the necessary operations for the solution of the tasks are described. The evaluation is, however, very general and holistic, and not focusing in detail on the specific parts of the operations or chains of operations used in them. Note: the difference between this substage and the next substage is only in the extensiveness of the answer. Subjects who fulfil the following criterion are included in this category:

- some basic components of the tasks are described vaguely: 'The effects of certain variables on others were studied in both tasks'; or 'In both tasks given knowledge should be combined with other knowledge, and it was also necessary to make combinations. How smaller components have an effect on the totality'.

4. LEVEL OF GENERAL ANALYSIS

The key indicator here is that the necessary operations for the solution of the tasks are described. The evaluation is, however, very general and holistic, and not focusing in detail on the specific parts of the operations or chains of operations used in them The subjects fulfilling next criteria are included in this category:

> - 'Both tasks had a similar structure. They included variables whose interaction was studied. The only way to study the effect of any variable was to keep the other variables constant and change only one variable'; or: 'In both tasks many possibilities had to be considered at the same time and one had to reason how one variable affected either the formation of colour or the swings of the pendulum. There were three variables in the pendulum experiment. By keeping some variables constant it was possible to arrive at the right conclusion. In the chemicals I had to make more assumptions, that is, to guess'.

5. LEVEL OF DEVELOPING SPECIFIC ANALYSIS AND INTEGRATION

The subjects are able to differentiate and reduce thought operations and chains of reasoning to smaller components. The differences and similarities between the chains of logical reasoning used in both tasks are analysed in greater detail than in the former substage. There is a tendency to combine the tasks with a single factor or factors found in both tasks. Note: answers in this substage are less extensive than in the latter, highest substage. Subjects who fulfil the following criterion are included in this category:

> - 'Similarities: in both tasks there were variables, the effect of which on the results of the experiments wasn't known. The effect of the variables had to be studied in such a way that by changing only one variable it was possible to conclude the effect. With this knowledge it was also possible to change the value of another variable, and to understand its effect. This method was applied for each variable, until the effects of all of them were found. Differences between the tasks: because the method just mentioned was in my view the most important factor, the following differences do not change my opinion that the tasks were clearly similar to each other. In the Pendulum task there were 3 variables, in the first Chemicals experiments there were 4 and in the second experiment also 4 (the liquid X was always present, i.e. it was constant)'.

6. LEVEL OF SPECIFIC ANALYSIS AND INTEGRATION

The subjects are able to differentiate and reduce thought operations and chains of reasoning to smaller components. The differences and similarities between the chains of logical reasoning used in both tasks are analysed in greater detail than in the former substage. There is a tendency to combine the tasks with a single factor or factors found in both tasks. The subjects fulfilling the next criterion are included in this category:

> - 'In both tasks I conclude that the final results were arrived at by varying one variable one at a time. In the Chemicals task there were more variables than in the Pendulum task. On the one hand, in the Pendulum task the number of variables was always constant, and on the other hand in the Chemicals task the number of variables varied from 2 to 5. This means that there were more variables affecting the final result in the Chemicals task than in the Pendulum task. In both tasks I used the so called 'elimination technique'. In the Pendulum task it was possible to examine the effect of one variable by comparing two experiments pairwise, the other variables being constant. In the Chemicals task I had to compare more experiments with each other than in the Pendulum task, because there were more variables in that task. No conclusions can be made concerning the nature of the liquids or the number of colour-forming liquids by varying only one variable and keeping the others constant, as was the case in the Pendulum task. In the Chemicals task the experiments could be examined on two levels: (a) it was possible to conclude how a certain liquid affects the final result or (b) how many liquids were needed in order to obtain the coloured liquid. (And on a third level: it was asked in the task to speculate the nature of one liquid if there was water or not in one glass!). In the Pendulum task I found that there was only one level of examination and evaluation, i.e. how certain variables (length, weight and swing) affect the result. From this viewpoint the Pendulum task was easier than the Chemicals task. On the Chemicals task there was also one 'extra' variable, namely liquid X, which made the task more complex, as it was the liquid whose nature was not known, and which was constant all the time and was in combination with all the other liquids. Stated on other way: the tasks were similar when evaluated from the viewpoint of decision making, but were different in terms of their task characteristics (i.e. the number of variables, the different 'essence' (nature) of the liquids, and on the number of experiments needed to reach a conclusion). In the Chemicals task it was possible only to reach a conclusion concerning the number of liquids needed to produce the coloured mixture, and in the second chemicals experiment it was possible to conclude that none of the liquids alone was sufficient to create the coloured liquid with X'.

APPENDIX 9

SUMMARY OF THE CONTENT ANALYSIS

1. What kind of skills and competencies do you need in your studies?	
Content category	**f**
1. Academic thinking skills: 1A. Critical, analytical and creative thinking	
Analytical thinking and gerenal thinking skills	17
Critical thinking	32
Scientific thinking	4
Metacognitive skills	1
Creatitivity, to create own perspectives	6
Conceptual thinking	1
1. Academic thinking skills: 1B. Logical reasoning and problem-solving	
Logical thinking, cause and effects, reasoning skills	20
Problem-solving skills	4
Objectivity	1
1. Academic thinking skills: 1C. Knowledge application	
Knowledge application skills	21
2. Student's active role, motivation and self-guidance	
Self-management, initiativeness, concentration	45
Diligence, stress control	18
Motivation	9
3. Subject knowledge, theoretical knowledge	
Theoretical and content knowledge (including common, mathematical skills, languages)	19
Theoretical thinking	4
4. Knowledge acquisition and construction	
Knowledge acquisition skills	18
Ability to process knowledge, to find the key points	23
Abilities to process new knowledge and to combine with existing knowledge	26
Abilities to construct knowledge entities	41
Argumentation skills	4
5. Generic skills	
Co-operation skills	14
Learning techniques, abilities of learning to learn	13
Communication skills	6
Memory	10

6. No special skills	
Common sense, everyday thinking	1
No special skills	4
Total	362

2. What is scientific thinking? Please, explain your answer.	
Content category	**f**
Short expressions	
1.Objective thinking	
Objectivity	16
Keeping one's own opinions, attitudes and emotions separate from scientific thinking	10
2. Critical thinking	
Critical thinking, ability of questioning	45
Analytical thinking	15
Explorative way of thinking	2
3. Fact-based	
Thinking, which is based on research	17
Complicated thinking	2
Exact, detailed thinking	2
Thinking, which is based on true facts	2
Abstract thinking, not context dependent, using concepts in thinking	4
More extensive expressions	
4. Ability to use knowledge and theories	
4a) Apply knowledge	
Ability to use theories and scientific knowledge	15
Making conclusions, ability to use theories and knowledge	9
Making deductions on the base of theory	5
Ability to use theories and knowledge in practise, ability to apply knowledge	9
Ability to evaluate the validity of the generalization of the research results	2
Ability to use and combine knowledge and theories in construction of new knowledge	2
4b) Construct new knowledge based on existing knowledge	
Constructing new models and theories based on old ones, making synthesis	12
Constructing new models and theories by questioning old ones and changing conceptions	12
Finding the key points, contructing theories	4
Inductive thinking	7
5. Extensive thinking including various perspectives	
Ability to sketch things as part of totalities and to divide the totality to separate parts	17
Ability "to find and define " the problem and ask the right questions	3
Ability to separate essential from the less essential (set things to order of importance),	6
Seeing things from versatile viewpoints /perspectives/knowledge sources and understanding	25
Comprehensive thinking	5
Taking into consideration the possible effects of the context.	5
6. Use of scientific methods	
6a) Use of scientific research methods	
Applying scientific research methods, which guarantees the validity, qualitative and quantitative methods, analysis based on tha data	11
To set the hypothesis, hypothesis testing	8
Mathematical thinking, statistical sciencies	3

6b) Logical thinking, causal reasoning Finding cause and effect, causality, finding explanations Finding the effects by changing one factors at a time Logical reasoning Systematic thinking	17 1 17 10
7. Creativity to form own conceptions (own way of thinking) Creative thinking Creating own views and conceptions, independent thinking Motivation, enthusiasm in thinking and an inquisitive approach to learn and understand. Deep understanding of knowledge To gain and have a deeper perspective	 8 7 4 6 5
8. Other a) Metacognitive abilities to identify one's own thinking processes Metacognitive abilities to identify one's own thinking processes b) Communication skills and interaction in adacemi Communications skills Interaction within the academic community and other researchers c) Technical skills to acquire knowledge Technical skills of acquiring knowledge d) Other I don't know Other than using common sense in thinking Similar thinking than other thinking Ability to view things scientifically Problemsolving Patience in thinking Developing oneself	 3 2 2 4 2 1 2 1 2 1 1
Total	**371**

3a. How is scientific thinking promoted in your studies?	
Content category	**f**
1. Final phase of studies, Master's thesis/diploma work	
Final phase of studies Master's thesis/diploma work	5 22
2. Methodological studies, courses of scientific thinking and argumentation	
Methodological studies Courses of scientific thinking and argumentation	7 3
3. Subject studies and course contents	
Course contents, literature Theoretical knowledgebase of studies	12 7
4. Orientation in teaching, teaching methods	
Teaching methods, which promotes to think with various perspectives and in a comprehensive way Teaching is scientific Critical thinking is emphasised	 7 7 9
5. Learning methods	
Projects, cases, problem based learning, essey writing Co-operation and discussions, group work, interaction with professors and researchers Independent studies	16 5 8

6. Scientific thinking is a prerequisite for studying	
Knowledge acquisition and processing skills are needed in studies Own thinking and perspectives are needed in studies Abilities of constructing knowledge and application of knowledge are needed in studies Understanding of causalities and cause & effects are needed in studies	8 11 4 2
7. Other	
Scientific thinking is possible to enhance if you have motivation. It is possible to study in higher education without abilities of scientific thinking	4
Total	137

3b. If not, why do studies not promote scientific thinking?	f
There are no space for critical thinking and own perspectives	4
Studies include too narrow perspectives	3
There are not enough group works and co-operation	1
Exams and skills of good memory are emhasised too much	2
Total	10